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A Comparative Assessment

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Chinese Idiom
"*To search the truth from facts*"

For Aiwa

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List of Abbreviations

ASMRAD	Act on Special Measures for Reservoir Areas Development
CSD	Commission on Sustainable Development
DSMC	Dam Safety Monitoring Center (PR China)
EIA	Energy Information Administration
EIA	Environmental Impact Assessment
GHG	Greenhouse Gases
GS	Gold Standard
IPCC	Intergovernmental Panel on Climate Change
IEA	International Energy Agency
IRENA	International Renewable Energy Agency
IWT	Inland Water Transport
JDEC	Japan Dam Engineering Center (Japan)
LCOE	Levelized Cost of Energy
LDSSC	Large Dam Safety Supervision Center
MLIT	Ministry of Land, Infrastructure, Transport and Tourism (Japan)
MoC	Ministry of Construction (Japan)
MWR	Ministry of Water Resources (PR China)
NGO	Non-Governmental Organization
RIS	Reservoir Induced Seismicity
RMU	Reservoir Management Units
RoR	Run-of-the-River
SD	Sustainable Development
SNWTP	South-North Water Transfer Project
TEU	Twenty-Foot Equivalent Units
TGD	Three Gorges Dam
UN	United Nations
UNCED	United Nations Conference on Environment and Development
UNCSD	United Nations Conference on Sustainable Development
UNEP	United Nations Environment Program
UNFAO	United Nations Food and Agriculture Organization
WCD	World Commission on Dams

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1. Introduction

Renewable energy is often seen as a salvific tool to fight global warming and climate change. “Renewables” offer indeed a wide array of advantages compared to other energy types: they are able to provide virtually inexhaustible energy supply, their pollutant emissions are generally considered to be only a fraction compared to combustion based power plants, and they do not involve the security risks of nuclear power plants (Intergovernmental Panel on Climate Change, 2012: 7-14).

Nonetheless, to argue that renewables are a superior type of energy generation by default would be a very far-fetched notion. Each type of (renewable) energy features its own distinctive set of advantages and disadvantages. Accordingly, the stereotypical perception of “last century’s” fossil fuels versus the “21st century’s” clean, sustainable and environmentally sound “green energy” should be replaced by a fact oriented analysis in order to find the most suitable form of energy generation for any given situation. The goal of this thesis is to contribute to such a development by evaluating one specific type of renewable energy, hydropower, and its performance variations in two different countries – the People’s Republic of China (PR China)[1] and Japan.

Hydropower was selected for two main reasons: Firstly, it is the most mature among all renewable energy technologies, having benefitted not only from more than one century of development, but also from technological spillover effects of conventional power plant technology, such as improvements in turbine construction. Despite their recent technological advances and popularity, other types of renewable energy, such as solar, wind or geothermal, are still far from the technological sophistication that hydropower has achieved (Australian Renewable Energy Agency, 2010). Secondly, the countries analyzed in this paper, the PR China and Japan, already have an extensive history of, and experience with hydropower, providing a substantial foundation for a comparative assessment.

In the light of this outstanding role of hydropower among the renewable energy sources deployed in the two countries, the question arises, whether hydropower is also the most

[1] Hereinafter, "China" and "PR China" will both be used as references to the People's Republic of China.

effective renewable energy source for the two countries. Accordingly, this paper will answer the following research question:

How effective is hydropower for the PR China and Japan in order to achieve further progress in their respective energy sectors?

The central term in this context is *effectiveness*. It is defined as *"the extent to which an activity fulfills its intended purpose or function"* (Harvey, 2004).

The intended purpose was provided by the countries themselves in recent national strategy papers. For the PR China, this is primarily the 11th and 12th 5-Year –Plan (Pan, 2005; Hong et al., 2013: 1533), as well as the Long-term Development Plan for Renewable Energy (可再生能源中长期发展规划) (中华人民共和国国家发展和改革委员会 National Development and Reform Commission, 2007) while Japan's ambitions are mostly summed up in the 2002 Act on Special Measures Concerning New Energy Use by Operators of Electric Utilities (電気事業者による新エネルギー等の利用に関する特別措置法) (Inoue and Shiraishi, 2010: 85) and the 2011 Act on Special Measures Concerning Renewable Energy Electric Procurement by Operators of Electric Utilities (電気事業者による再生可能エネルギー電気の調達に関する特別措置法) (Kojima, 2012) respectively. The primary objectives for the transformation of their energy systems highlighted in these core documents include:

- Increasing generation capacity in order to provide sufficient energy at reasonable prices to support their respective economies
- Transforming the energy system to induce less ecological impacts and to protect the livelihood foundation of their people
- Becoming less dependent on energy imports for both financial and geo-strategic

The first and third core points are covered by default: with a domestic technically exploitable hydropower potential of 2474 terawatt hours (TW/h) and 136 TW/h and a current utilization of only 580,000 gigawatt hours (GW/h) and 74,144 GW/h for China and Japan respectively, there is plenty of room to increase to hydropower based energy generation. (World Energy Council, 2010: 298; 304)

In essence, these objectives aim at improving the long term performance of the energy sector, by better harmonizing it with economy, society and environment. This goal is reflected by the concept of Sustainable Development (SD). Therefore this paper will utilize a sustainability assessment in order to analyze hydropower performance in the PR China and Japan.

The majority of contemporary sustainability assessments concentrate on either large scale (e.g. a country in general), or on very small scale projects (e.g. a single power plant). Sustainability analyses on a small scale can rely on a large amount of very specific data which can be obtained directly from the source (e.g. the operating company). On the negative side, results gained from such assessments cannot be treated as representative. Large scale analyses on the other hand usually have to rely on highly aggregated data sets (e.g. “life time of proven uranium reserves” (International Atomic Energy Agency, 2005: 202-203)) and while such an approach can produce valid general statements, the analytic accuracy is significantly lower compared to project specific assessments (International Atomic Energy Agency, 2005: 202-203). In contrast, this thesis utilizes an intermediary approach: analyzing one specific sector on a country-wide basis.

This poses some challenges in regards to the utilized data: most small scale data often cannot be used due to being too specific and not representative. Aggregate data on the other hand have to be more specific and narrow than a large scale analysis would usually require. Accordingly, the data limitations are inherent to the chosen approach, which is both consequence of and reason for the lack of similar analyses. This paper will show that it is indeed possible to conduct a sector-wide sustainability assessment on a country scale, thereby contributing to fill existing gaps in SD theory.

It is common consensus in SD theory that the sustainability performance varies according to a range of specifics, such as choice of technology, regional topology etc. (e.g. The Gold Standard Foundation, 2012) This paper builds upon and extends this understanding: It argues that regional differences for sustainability performance are not only measureable on a project and site by site basis, but also on a national level. While the results of such an assessment are necessarily of lesser analytical accuracy than those of a project specific analysis, the limitation to hydropower and an interdisciplinary approach to data gathering make it possible to reach very tangible results.

In addition to the contribution to SD theory, the value of this paper stems from the application to the PR China and Japan by replacing the perceived utility of hydropower (often based on superficial, one-sided or outdated assessments), with an interdisciplinary, comprehensive and fact based analysis, which also takes into account dependency on country characteristics.

The PR China and Japan have been chosen for this comparative analysis because they progressed along highly different paths for the development of their respective energy sectors, and yet, the challenges they face in 2014 and beyond are surprisingly similar.

The **PR China** has experienced massive industrial growth throughout the past three to four decades. Subsequently, the energy demand also increased significantly. Over the last five decades it has multiplied approximately 25-fold (McKinsey, 2009). Due to its rich domestic deposits and the relatively low cost of mining and refining, coal has been, and still is, the dominating energy source, accounting for nearly 80% of China's total energy generation (Chen, 2004: 1). While it provided the necessary electric capacity for rapid economic development, this coal dependency has also caused significant environmental damage (McKinsey, 2009). Since China's energy demand is likely to further increase, decision makers have been looking to improve the country's energy sector, not only in terms of available capacity but also to decrease negative external effects of unsophisticated combustion based generation technology. Accordingly, clean energy and environmental protection are of high importance for Chinese decision makers, as demonstrated by the increasing promotion of renewable energy development by Chinese authorities: The 11th 5-Year-Plan (2006-2010) proclaimed the goal to double the share of renewable energy until 2020, from currently 7% to 15% of China's total energy production. These plans also include a 40% reduction of carbon emission compared to the level of 2005 (ChinaCSR, 2008). To achieve these ambitious goals, the government in Beijing relies heavily on hydropower. This is not only due to the fact that hydropower is, compared to other renewable energy sources, already fairly developed and tested, but also because China has the world's largest economically exploitable potential: A total of 1753 TW/h per year – which exceeds the combined value of the United States, Russia and Canada (International Renewable Energy Agency, 2012: 13).

In **Japan** the energy sector's development has progressed vastly different. The country already had its major renewable energy boom in the form of massive hydropower buildup shortly prior and after World War II and especially during the 1950s (Inoue and Shiraishi, 2010: 81-82). Since then, Japan has slowly turned away from hydropower and concentrated more on other energy types: The hydropower share of the Japanese energy mix decreased from more than 30% in 1950 to 7% in 2010 (Energy Information Administration, 2012: 9).

The reason for this development was not an actual decrease in hydropower output. In fact, the gross output of hydropower kept increasing, as old plants have been upgraded and new ones constructed. Instead, the "marginalization" of hydropower was due to a much higher development rate in other energy sectors, especially nuclear power, which became the primary focus of Japanese energy development in the early 1960s (Inoue and Shiraishi, 2010: 81-82). Its share increased by almost 20 times between 1973 and 2005**.** In 2010, Japan was ranked third in the list of countries with the highest share of nuclear energy in their generation mix with almost 30% of its energy being generated by nuclear power (Energy Information Administration, 2012: 9). The association of power companies was heavily invested into nuclear energy and significantly influenced the energy discourse in Japan for decades, which led to a broadly uncontested central role of nuclear energy in Japan. (DeWit and Tetsunari, 2011).

This changed in the aftermath of the 2011 Tohoku (東北地方） earthquake. Following a massive seaquake at the tectonic fault lines near the Pacific Rim, a 9.0 magnitude earthquake hit the Japanese mainland, followed by a massive tsunami. The nuclear power plant Fukushima Dai-Ichi (福島第一原子力発電所） was heavily damaged, which resulted in massive leaks of radiation and contaminated materials. The Fukushima incident is widely considered as one of the most devastating events at a nuclear power plant in history, second only to Chernobyl. It had a significant impact on the Japanese society and its stance towards nuclear power. While Japan never had a strong green movement,[2] the Fukushima accident mobilized a massive opposition towards the nuclear valley (Stolten and Scherer, 2013: 14). As a result, all of Japans nuclear power reactors were shut down and it remains unclear if any will return back to the grid (NY Daily, 2013). To compensate for the loss of almost one third of its domestic energy generation, Japan is forced to spend significant resources on the import of additional energy, specifically in the form of natural gas and oil at a still increasing price (Energy Information Administration, 2012: 14-18). The aggregation of these factors massively endangers Japans energy security Renewable energy offers the arguably best mid

[2] While the civil movement during the 1960s and early 1970s targeted environmental pollution, it did so only as a means to an end. The goal was to fight the severe health issues (caused by primarily pollution), such as the Itai-Itai or Minamata diseases. This movement has therefore to be considered a public health movement and not a "green" one (Hirata, 2002: 25-28).

to long term solution to these problems. Among the different renewable energy options available to Japan, a strong emphasis lies on hydropower. With 7% in 2010, hydropower contributed more than twice the electricity to the grid than all other types of renewable energy combined (Energy Information Administration, 2012: 9). As a result, infrastructure, company expertise and experience of local governments and affected citizens are also higher than for any other RE type. Therefore any massive RE development in Japan is likely to prioritize hydropower in order to rely on existing strengths of the Japanese economy and society, making it not only a viable choice for Japanese decision makers but also for this assessment.

To lay a foundation of current research in the field, the following chapter will discuss the current state of the art of interdisciplinary assessments of hydropower. Before the methodological and empirical analysis may commence, it is essential to provide a specific definition of the core terms used in this paper. Chapter 3 will therefore start with a discussion of different technological variants of hydropower, their implications and utilization in this paper. Subsequently, the chapter will discuss the concept of Sustainable Development (SD), its most important interpretations, their implications and the definition utilized in this paper. Chapters 3.3 to 3.7 introduce the indicators used in this paper, their contribution to the assessment and their evaluation. In chapter 4, the empirical assessment is conducted based on the indicators presented in the previous part. Finally, chapter 5 features a comparative summary of the results of this paper and the conclusion.

2. State of the Art

"Large dams, perhaps more than any other large infrastructure project, represent a whole complex of social, economic and ecological processes."

(McNally, Magee, Wolf, 2008: 286)

It is this multitude of influences and intertwined relations that make a complete assessment of reservoir based hydropower so difficult. Since the kind of interdisciplinary approach utilized in this paper originated from a relatively young academic field, there is currently no equivalent piece of work that is utilizing the sustainability theory to compare hydropower performance in different countries, let alone including China and Japan. To assess how other scholars have dealt with topics similar to this paper's research question, it is therefore necessary to extend the scope and examine how other researchers have assessed hydropower performance on a country basis in general.

McNally, Magee and Wolf have opted to utilize a sustainability model in their paper "*Hydropower and Sustainability: Resilience and Vulnerability in China's Powersheds*". While they base their research on SD theory, the framework is heavily modified. Instead of the traditional three pillars of social, economic and ecological sustainability, they use two combined ones: "socioeconomic" and "biophysical", to which they add a third pillar, the "geopolitical" system. Those three modified pillars provide the foundation for the assessment of a hydropower project's resilience and vulnerability, for which they provide four and six indicator factors respectively. The authors argue however, that Sustainability is a rather intangible concept, which needs additional support to become applicable. They have chosen to utilize the concepts of "resilience" and "vulnerability" for this task. Those concepts analyze the "*ability of biophysical systems to adapt to change*" (McNally, Magee, Wolf, 2008: 287), particularly in the context of human influence and interaction. Their research objects are mainly large scale dams in China, with a focus on the Nu River. While the three authors claimed that their approach is based on sustainability theory, supported by resilience and vulnerability, the execution of their analysis suggests otherwise. Their paper is clearly focused on the geopolitical approach – out of the ten indicator factors provided, seven are exclusively related to the geopolitical system. As a result, their paper lacks any significant inclusion of biophysical and socioeconomic arguments, whose equal inclusion is a core requirement for a SD approach.

An additional point of critique is the fact that McNally, Magee and Wolf do not fulfil their self-proclaimed task: their paper does not answer whether the Nu River is vulnerable or resilient and neither does it provide tangible arguments and facts, despite this being the very reason why they included the resilience and vulnerability approach in the first place (McNally, Magee, Wolf, 2008: 292-293).

Another approach has been developed under the name of Integrative Dam Assessment Model (IDAM), by Kibler, Tullos, Tilt, Wolf, Magee, Foster-Moore and Gassert, and also been applied to Chinese hydropower development (*A Users Guide to the IDAM Methodology and a Case Study from Southwestern China*, 2012). This framework is based on the same modified three pillar approach (geopolitical, socioeconomic and biophysical) that was already used by McNally, Magee and Wolf in 2008, which is not surprising, considering Magee and Wolf were part of both teams. Each of the pillars consist of seven indicators and for each of them a negative and positive potential scope of impact is provided (2012: 10-15). However, not only are most of those indicators are very broad, e.g. *Wealth*, *Infrastructure* or *Macro Impacts,* but some of them are also very difficult to assess in an objective and tangible way, e.g. *International Political Stability* or *Material Culture* (2012: 10-15).

Nonetheless, their IDAM approach is very structured and during their China assessment they apply it in a very technical way that reduces subjectivity as the following example shows:

> IF **DAM** provides no hydroelectricity OR flood control OR irrigation,
> THEN **NO IMPACT**
>
> IF **DAM** is 1st to 33rd percentile for hydroelectricity OR flood control OR irrigation, THEN **SMALL IMPACT**
>
> IF **DAM** is 34th to 66th percentile for hydroelectricity OR flood control OR irrigation, THEN **MODERATE IMPACT**
>
> IF **DAM** is over 66th percentile for hydroelectricity OR flood control OR irrigation,
> THEN **LARGE IMPACT**

Geopolitical Indicator 1: Domestic Shock (Kibler et al., 2012: 27)

While providing a very sophisticated graphical summary of their findings, their case study unfortunately lacks a written conclusion that sheds light on potential problems, mutual influences and other points of interest that might have occurred during or resulted from their assessment. Nonetheless, they provided one of the most sophisticated methodological frameworks for the comparative assessment of hydropower, and the only *major* point of critique can be aimed at their indicators selection.

Another highly valuable approach of hydropower assessment is developed by the non-profit organization International Hydropower Association (IHA): the *Hydropower Sustainability Assessment Protocol* (2010). Experts from various countries (including PR China, Norway, Tasmania, Germany etc.), as well as from different professional backgrounds (academia, business, international organizations) have contributed to this framework. The 220 page document discusses a total of 23 indicators, not only from the traditional three sustainability pillars, but also several separate indicators such as “Governance”, “Communications and Consultations” or “Demonstrated Need and Strategic Fit”. Unlike most other frameworks, the Hydropower Sustainability Assessment Protocol applies those indicators on four different stages of hydropower development: “early stage”, “preparation”, “implementation” as well as “operation” (2010: 7), resulting in a very extensive analysis. Unfortunately, the *Hydropower Sustainability Assessment Protocol* does not provide guidance on how to combine those different assessments in order to reach a final result.

In addition to approaches which utilize a SD approach to assess effectiveness, there are also various others which concentrate on one specific performance area, e.g. social, environmental or economic, but rely on sustainability for additional background information and analysis.

Yüksel (“*Development of Hydropower: A Case Study in Developing Countries”*, 2007) for instance concentrates on the economic feasibility and performance of hydropower development for developing countries. Analyzing countries such as India, China and Turkey, Yüksel places special emphasis on cost structures and other economic indicators, but includes sustainability in order to further promote hydro power due to its social and environmental benefits (2007: 119-120). Unfortunately, Yüksel’s analysis is asymmetric in its usage of facts and data: the economic main part utilizes various sources and data to support its arguments, while the proposed social and economic benefits are for the most part outdated, superficial or even plain wrong, e.g.: “*Small hydropower represents an alternative to fossil fuel generation* *and does not contribute to either greenhouse gas emissions or other atmospheric pollutants." (2007: 120),* which clearly ignores recent findings about reservoir based emissions.[3]

Tilt, Braun and He take a similar general approach. In their paper "*Social impacts of large dam projects: A comparison of international case studies and implications for best practice*" (2009), they conduct a social impact assessment of large scale hydropower in China (upper Mekong) and South Africa (Lesotho Highlands). While termed social, their analysis includes significant economic considerations and analyzes the impact of social developments on the whole rural economy. In addition to that, the authors base their social impact assessment on a definition which also includes ecological consideration, called "biophysical environment" (2009: 250). Similarly to most other works presented in this chapter, Tilt, Braun and He also do not provide an argumentation that relies primarily on empirical data and produces tangible results. Additionally, they also did not conduct a comparison of their two major case studies, despite this being the very title of their paper.

[3] See Chapter 4.2.1 for a more detailed analysis on hydropower related Greenhouse Gas emissions.

3. Methodology

3.1 Classification of Hydropower Stations

Firstly, it is important to separate hydropower from the second type of water-based energy generation: ocean power. Ocean power is an emerging renewable technology that utilizes tidal movements, currents, waves or ocean thermal energy to generate electricity. Ocean power plants are – due to their technical design – limited to application in salt waters and are typically located at the seabed. Consequently, ocean power has a completely different set of benefits and impacts on their environment compared to hydropower (Geoscience Australia, 2014).

Hydropower, on the other hand, is exclusively located above water and typically harnesses energy from fresh water sources, primarily rivers. It is a frequently used term that comprises various different technological approaches which consequently also shape the set of indicators that have to be used for a sensible sustainability assessment of hydropower.

One factor all hydropower based technologies have in common is ability to respond to demand fluctuations in a timeframe of minutes, which makes it inherently more flexible than most other energy sources. Thermal combustion based plants for instance require up to several hours to adjust their output, while most other renewables are subject to external effects that cannot be controlled, such as sunshine or wind speed. Hydropower also enables the storage of power potential for weeks and months, further enhancing its viability as one of the prime energy sources to deal with demand fluctuations. Regarding the different technological approaches to hydropower, there are three major types: Run-of-River (RoR), Pump Storage and Reservoir (Intergovernmental Panel on Climate Change, 2012: 83-85).

Run-of-River systems are the least deployed type of hydropower in China and Japan (see page 23; Food and Agricultural Organization of the United Nations, 2013b). These plants are located at a river and utilize a dam to generate electric power from the water flowing through it. They do not have a reservoir attached and are therefore not able to provide most of the benefits associated with reservoirs (e.g. water and thereby energy storage, water supply for irrigation etc.). As a positive tradeoff however, they also do not exert most of the negative impacts caused by reservoir systems, such as safety risks, sedimentation issues, etc. (Inoue and Shiraishi, 2010: 81).

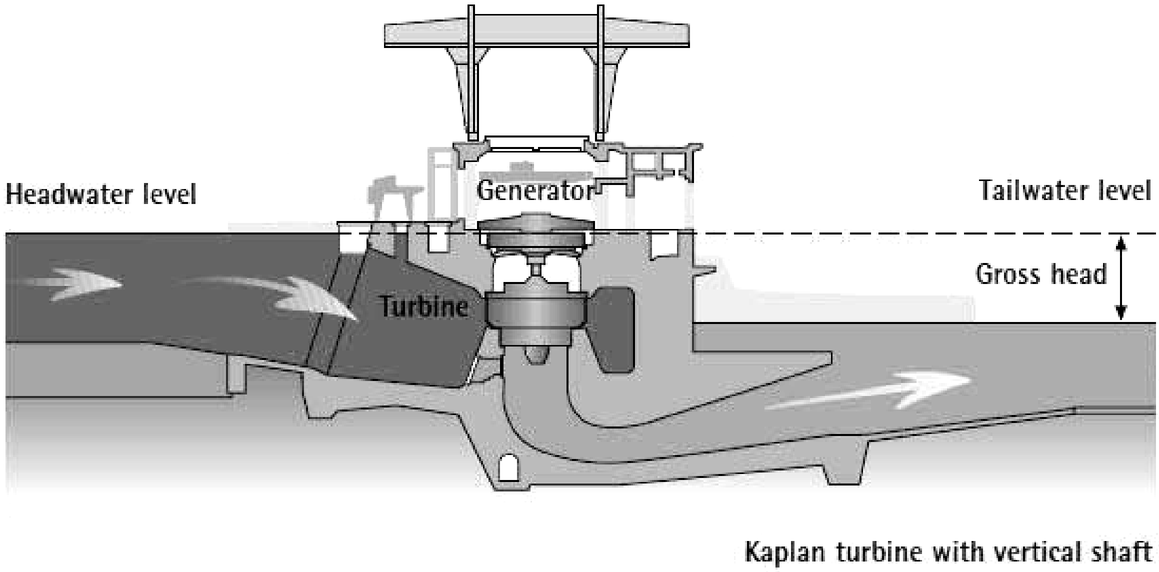

Figure 3.1: Run-of-River type Hydropower Station (OEVSV, 2011)

The second type of hydropower plants is the so called **Pumped Storage** system (see Figure 3.2). It typically is located in close proximity to a river. Pump storage systems are not power plants in the classical sense, but more of a storage system. In times of low demand, excess energy is used to pump water up to a reservoir at higher altitude. This water can be used to provide additional energy through a classical dam-turbine system in order to quickly react to demand changes (Inoue and Shiraishi, 2010: 81).

The third type of hydropower stations, **Reservoir based** (see Figure 3.3), are the most commonly deployed ones in China and Japan and are mostly associated with the term of hydropower. Typically located at a river, energy is generated by a controlled flow of water through the dam’s turbines. The storing of large water masses in the reservoir produces multiple benefits: The increased water pressure and flow at the penstock for instance leads to superior generation efficiency by increasing the force through which the turbines are powered. Additional benefits include water supply for irrigation, public or industrial use, recreation options etc. (Inoue and Shiraishi, 2010: 81).

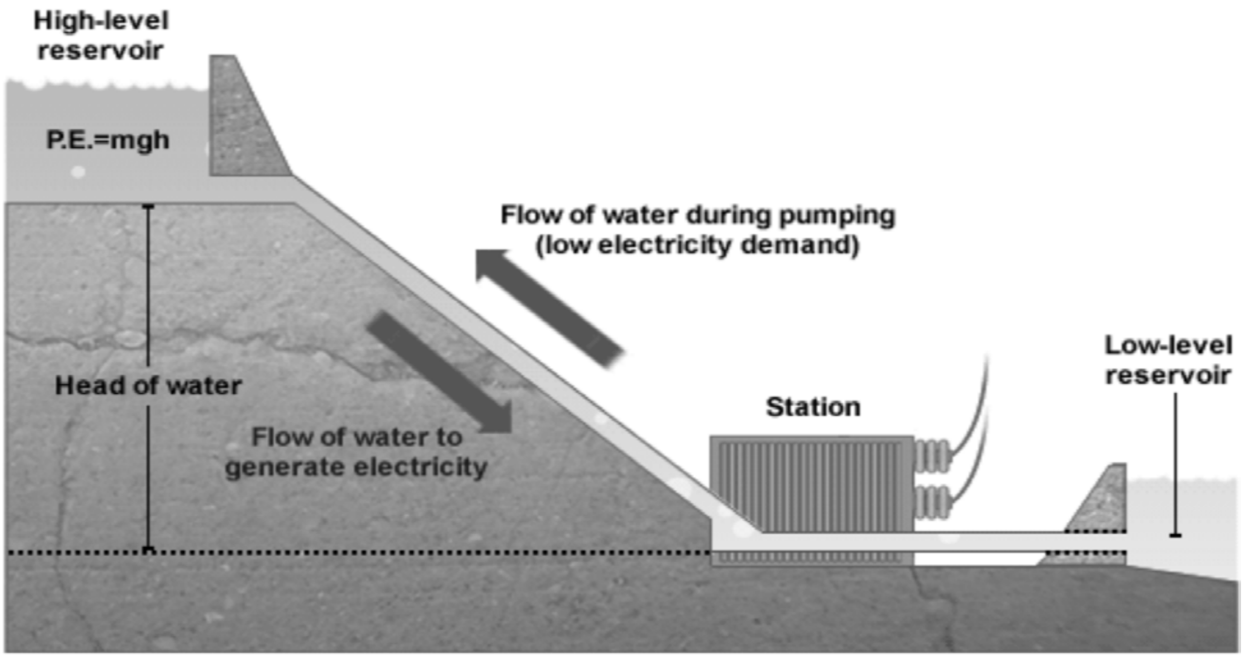

Figure 3.2: Hydropower Station (Pumped Storage) (BBC, 2014)

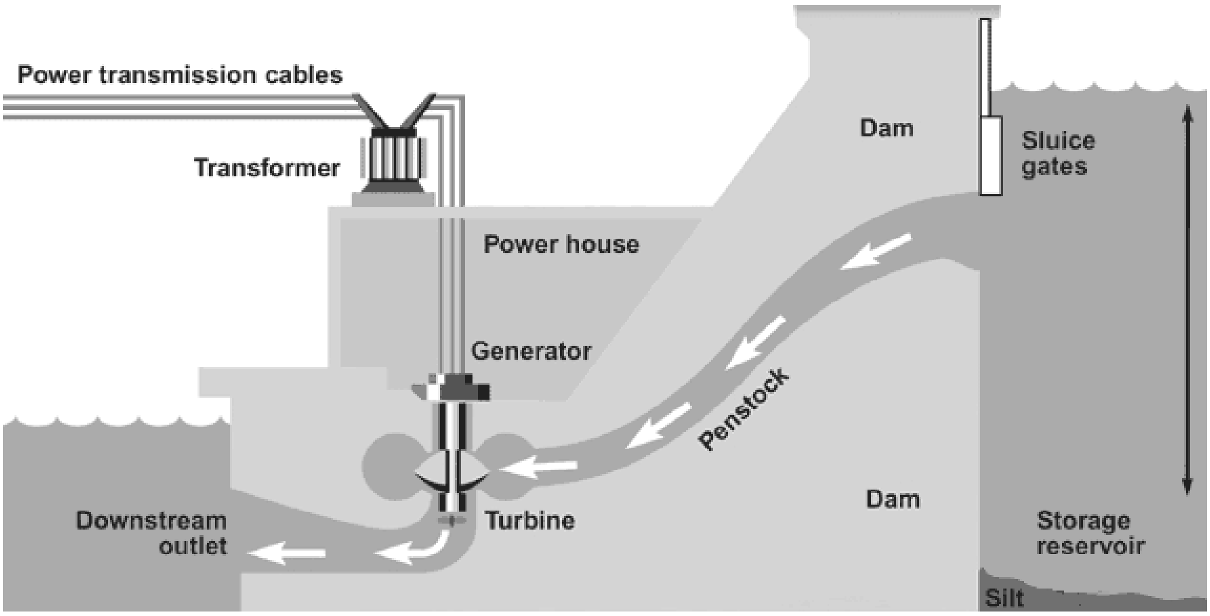

Figure 3.3: Hydropower Station (Reservoir) (Perlman, 2014)

Occasionally, literature describes a fourth type, *Multipurpose Dams,* which is essentially a reservoir dam, but the priority might not be electricity generation at all times, but rather flood control or water supply. A high water demand, e.g. for irrigation purposes during a drought, might prevent additional water discharge for electricity generation. For the purpose of this analysis, the differentiation between a multipurpose and a normal reservoir dam is not taken into account, because the advantages, as well as the disadvantages, are similar and the differences are only related to how the dam is operated (Intergovernmental Panel on Climate Change, 2012: 462).

Another common way to differentiate hydropower is by scale. The Three Gorges Dam (TGD) in China, for instance, is one of the largest constructions built by mankind. On the other hand, small scale hydropower, which can even be deployed off-grid and function completely independent in remote areas, constitute a fast growing market (Intergovernmental Panel on Climate Change, 2012: 474). Unfortunately, there is no commonly agreed upon classification in regards to hydropower plant scales. Upper limits for *small* scale classifications range between 1.5 MW (Sweden) over 50 MW (China) to up to 100MW (USA) installed capacity (Intergovernmental Panel on Climate Change, 2012: 450).

Furthermore, while installed generation capacity is the most common way to assess the scale of a hydropower plant, it is not the only one (Intergovernmental Panel on Climate Change, 2012: 450). When including factors like reservoir size (e.g. area or capacity) or effective generation capacity, it becomes even more complicated to find a common denominator on how to classify hydropower plant scale. Additionally, there is a significant problem regarding available information and statistics.

Statistical data (and even most hydropower related research in general), almost always lacks tangible information about the scale of the power stations that have been assessed. Oftentimes, small scale plants are for instance not included in such data for various reasons (e.g. not being connected to the main grid or simply not known to the entity creating the data set).

In order to avoid those problems and the resulting distortion of this paper's methodological transparency and accuracy, the empirical analysis will primarily utilize dam-specific statistics provided by the United Nations' Food and Agricultural Organizations' (FAO) hydropower dam database. Their database comprises 543 and 722 entries for Japan and China respectively and more importantly, does not include dams that feature reservoirs which are too small to exert a noteworthy impact on their environment (Food and Agricultural Organization of the United Nations, 2013b). In the context of this paper, such an approach is a particularly fitting choice, since artificially created capacity numbers do not make a statement about the actual impact on the dam's environment. Dams with very small reservoirs on the other hand, are technically more alike to Run-of-River systems, in that they have a distinctively different (and smaller) set of advantages and disadvantages. A hundred megawatt run of river plant for instance, might have a higher capacity and therefore qualify for analysis, while having a significant lower sustainability impact than a thirty megawatt reservoir plant which would not be assessed due to its “smaller” scale. Consequently, this approach falls in line with the initial reason why this paper assesses only reservoir based hydropower and excludes pump-storage and run-of-river systems.

Furthermore, for the following reasons neither pump storage nor run of river type plants will be included in this paper’s assessment. Pump storage systems cannot be considered power plants in the first place, due to the way they work and the fact that they need slightly more energy to operate than they can provide because of efficiency losses in the pump-discharge process.

Run of River systems are not included in the analysis because firstly, due to their significantly different construction and design approach (mainly their lack of a storage area), their impacts, advantages and disadvantages are very different from reservoir based hydropower plants. Therefore, Run-of-River plants require a separate assessment. Secondly, the contribution of RoR plants to the total amount of hydro energy generation in China and Japan is insignificant and therefore negligible. In China for instance, the 54 largest reservoir plants (with a capacity of over 1,000 MW), provide a combined capacity of 167,207 MW. This amounts to approximately 85% of the countries’ total hydropower generation capacity. In comparison, out of the largest RoR plants, only a single one (天生桥二 Tianshengqiao-II) surpasses the 1,000MW borderline, with only seven more plants surpass the 100 MW threshold, for a total of 3,854 MW RoR based capacity (Food and Agricultural Organization of the United Nations, 2013b).

3.2 The Concept of Sustainable Development

3.2.1 Conceptual Foundation of Sustainable Development

The question whether or not, and to what degree a certain energy type is efficient and beneficial for a specific country is difficult to answer. How should priorities for such an assessment be distributed; does economic performance matter the most, preservation of nature, or rather achieving a state of autarky? The answer to this question is subject to individual priorities and values and can therefore vary significantly depending on the respondent. Sustainable Development is an optimal approach for such a task because it combines social, economic and ecological aspects and considers them on a background of interdependency and equality. It is for this reason that scholars and decision makers around the world see Sustainable Development as the landmark of effective energy policy (see for instance the Global Network on Energy for Sustainable Development, 2014; European Council, 2001; and Riahi et al., 2012).

It is not completely certain when, where and in which context and connotation the terms and concept Sustainable Development and Sustainability first appeared. During the early 1970s, they started to be used sporadically in official documents such as the *Action Plan for the Human Environment*, published by the UN Conference on the Environment (United Nations, 1972: 6-28).[4]

Other actors that began using those terms include various UN branches as well as environmentally oriented organizations such as the International Union for the Conservation of Nature (Allen and Edwards, 1995: 92). At that time, however, Sustainable Development lacked a commonly agreed upon definition and the term, arguably, did not transfer substantial tangible content, which is why its utilization in these early cases should not be overemphasized. It was more than a decade later that the first tangible and broadly accepted definition was proposed by the UN World Commission on Environment and Development's (commonly and henceforth referred to as the Brundtland Commission) report *Our Common*

[4] While the terms Sustainability or Sustainable Development were not yet explicitly mentioned in the *Action Plan for the Human Environment*, it is the first appearance of their basic principles. The document, for instance, encourages the training of personnel on how to incorporate environmental considerations into developmental planning, as well as identifying and analyzing the economic and social cost-benefit structures of projects (United Nations, 1972: 27-28).

Future in 1987. Their proposal has since become to one of the most widely recognized definitions:

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." (World Commission on Environment and Development, 1987: 37)

The report further identifies two key issues that are highly intertwined with Sustainable Development: The first prioritizes the essential *needs* of people (especially those affected by poverty), while the second one revolves around the current state of technology, social organization and environmental capacity and how these factors limit the provision of the aforementioned needs (World Commission on Environment and Development, 1987: 41).

Although it has received high appreciation and became the common denominator of further SD theory, the Brundtland definition is very broad and lacks conceptual preciseness. Correspondingly, the report as a whole has been heavily criticized for its vagueness, lacking sufficient processes for measuring progress, result evaluation, and concrete ideas on how to work towards Sustainable Development (Trainer, 1990: 71-84; Drexhage and Murphy, 2010: 6-10). A shortcoming that was even commented on in the report itself, but was considered necessary at the time to reach an agreement on a definition and convey the basic idea of sustainable development to a broader audience:

"We do not offer a detailed blueprint for action, but instead a pathway by which the peoples of the world may enlarge their spheres of cooperation"
(World Commission on Environment and Development, 1987: 11).

Despite the criticism it received, the Brundtland Report has to be considered the most influential development step for sustainable development. Not only did it provide the most basic commonly referred to definition of sustainable development, but it also initiated the transition of sustainability towards scientific mainstream. In the reports aftermath, academic attention for this matter increased significantly, sparking research and development towards much needed refinement of SD's theoretical foundation (Drexhage and Murphy, 2010: 6-11; O'Riordan and Jordan, 1999: 81-93).

Such refinement was achieved in 1992, at the United Nations Conference on Environment and Development in Rio (UNCED, also known as the Earth Summit). It included the declaration of environmental and developmental principles, the creation of the UN Commission on Sustainable Development (UNCSD) as well as the so called Agenda 21, a 300 pages proposal for implementing sustainable development in various areas (Stoddart et al., 2011: 6). Further progress was achieved during the International Conference on Water and the Environment in the same year (International Conference on Water and the Environment. 1992) and at the Millennium Summit in 2000, which continued this path with the proclamation of the *Millennium Development Goals* which were highly influenced by the idea of sustainability (United Nations, 2013; 3-4, 42-51; Loewe, 2012: 1-4).

The arguably most important transformation of SD theory since the Brundtland Report took place several years later, at the UN World Summit in 2005. There, the concept of three interdependent and mutually reinforcing pillars of sustainable development was presented to the public: *economic development*, *social development* and *environmental protection* (United Nations General Assembly, 2005: 11-15).
With those pillars being intertwined, the concept implies that development can only be sustainable if all of its constituting parts are sustainable on their own. Therefore, if only one of them is not fully sustainable, the whole development cannot be considered sustainable (World Bank, 2004: 9-10). The “three pillars” have since then become the foundation of most SD theories and have not only been utilized in countless academic publications, but have also served as the most common foundation for further development. While Sustainable Development in general is a field that has gone through substantial change and was subject to extensive discussions, the three pillars represent a generally accepted consensus and can be considered the smallest common denominator of SD theory.

3.2.2 Development Trends

General Interpretation

In light of the broadness of potential applications and importance of the concept of Sustainable Development, the theoretic foundation has been extended significantly over the past decades. While there has not yet been a theory that has surpassed the appeal of the

Brundtland definition and the three pillar model, SD theory continues to be developed and offers a wide range of approaches and interpretations that try to improve the concept from various angles.

Ronald J. Engel provides an interpretation that is significantly different from, and far broader than the Brundtland definition. According to him, Sustainable Development is:

"[…] *the kind of human activity that nourishes and perpetuates the historical fulfillment of the whole community of life on earth*." (Engel, 1993: 10-11)

The "community of life" on earth clearly indicates that while Sustainable Development is a human process, it has to guarantee the integrity of every other living entity. The Brundtland Report in contrast implies that impacts on the environment and other living beings should only be limited to the degree that they do not harm the "*ability of future [human] generations to meet their own ends*" (World Commission on Environment and Development, 1987: 37).

This neglect of environmental protection appears in the work of other authors as well, for instance in Pearce, Markandya and Barbier, who stated that SD means that "*these [social and economic] goals are sustained, i.e. that real incomes rise, that educational standards increase, that the health of the nation improves and that the general quality of life is advanced*" (Pearce, Markandya and Barbier, 1989: 42).

Weak Sustainability and Strong Sustainability

Another aspect of the discussion about SD definitions is the debate about weak versus strong sustainability. These concepts have been developed in the field of economics in order to attain an applicable SD definition (Dietz and Neumayer, 2007: 617-625). The core question is whether or not natural capital and man-made capital are substitutable.

According to the concept of weak sustainability, natural capital is substitutable by man-made capital. Consequently a situation can be considered sustainable if the savings rate exceeds the combined depreciation rate of natural and man-made capital, because the total capital stock does not decrease (Gutés, 1996: 147-148). The concept of strong sustainability on the other hand does not consider natural and man-made capital to be mutually substitutable. As a result, the loss of natural capital, such as a decrease in biodiversity cannot be balanced by an increase in man-made capital, such as increased GDP. Outside of economics, the notion of weak sustainability does not have a notable influence on the SD discourse and is not mentioned in any of SD theory's key documents. Strong sustainability is the common consensus of current research and political decision making (see its utilization in e.g. Millennium Summit, UN World Summit or UN Conference on Environment and Development, in the previous chapter). Something can only be considered sustainable if its components are sustainable as well. Making such an approach applicable requires the individual consideration of each component. If they were interchangeable, as the concept of weak sustainability suggests, the extinction of an animal species or the emission of a certain amount of Greenhouse Gases (GHG) could be considered "sustainable", as long as the power plant responsible for these effects generates sufficient energy or financial revenue. Such an approach is diametrically opposing a theory of SD that aims to meet "*the needs of the present without compromising the ability of future generations to meet their own needs."* (World Commission on Environment and Development, 1987: 37) because a dysfunctional ozone layer, for instance, would most certainly compromise the ability of future generations to meet their needs.

The "Fourth Pillar"

Another area of ongoing discussion is the addition of a fourth pillar to the traditional three pillar model of sustainability. One proposal is to include culture as the fourth pillar. Prominent backers of this idea are the Cultural Development Network and the UNCSD. They argue that culture is as essential to a functional society as the other pillars and that it "*fosters economic growth, helps individuals and communities to expand their life choices, is important to adapt to change and raising the resilience of social-ecological systems"*. Another argument by the UNCSD is that culture and cultural diversity may help to decrease the "*driving forces of unsustainability"* (United Nations Conference on Sustainable Development, 2012).

An alternative proposal is the inclusion of *governance* as a fourth pillar. Some scholars argue that despite the increasing adaption of the SD concept and its implementation in many areas of our life, the core problems such as environmental decay or poverty have not been solved, but sometimes even intensified. According to these experts, one of the main reasons for this development is the lack of sufficiently successful implementation, monitoring and (re-) evaluation. Furthermore, SD objectives have not been assigned the necessary priorities. Addressing the problems that SD was developed to address requires governance as a fourth pillar, in order to alter the decision making structure and priorities in a way that would favor the faithful and necessary integration of the other three pillars. It is important to note that in this approach, Governance as the fourth pillar has a unique role in that it is a prerequisite and a supporting factor for the other three pillars. (Stoddart, 2011: 10-13).

Despite the extensive development of SD theory and the large amount of approaches to further extend and modify the theory, the majority of approaches continues to rely on the Brundtland Report’s core idea of balancing all relevant parts of human environment and society (World Bank, 2004: 9-10):

“In essence, sustainable development is a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development; and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirations.” (World Commission on Environment and Development, 1987: 43)

While there are viable reasons for the introduction of a fourth pillar, there are also several problem with it, irrespective of whether the fourth pillar would feature culture, governance or any other area. Those variants are characterized by a severe lack of applicability. Their respective discussions have been centered about if, and why they should be included into the SD theory. Meanwhile, progress towards applicability (e.g. identifying relevant indicator or developing evaluation mechanisms) has not yet been made. As mentioned before, this paper takes a different approach and evaluates performance (through the concept of Sustainable Development) on a country-scale, which creates a unique new set of challenges regarding both methodology and data-gathering. Hence it is important to have a solid and transparent foundation that avoids further complications on a methodological level. Accordingly, this thesis’ methodological approach will be based on the traditional strong sustainability - three pillar model.

3.2.3 Indicator Identification

Having developed a working definition of sustainability and its main components, the most important task is to achieve what the Brundtland Report (and many other SD theories) failed to do and was criticized heavily for: developing measures to analyze and evaluate processes as well as set specific goals towards Sustainable Development. Since the main pillars, social sustainability, economic performance and ecological protection, are such broad areas, indicators are of great importance for the practical application of SD theory.
Regarding such indicators, it is important to note that the scale of sustainability assessments can vary greatly. In theory it is possible to assess the sustainability rating for a single dinner menu (Müller et al., 2013) as well as for the research objects on a global level (World Bank, 2004: 10). However, any increase in assessment scale implies a tradeoff in terms of analytical accuracy.

Several international organizations are active in developing general indicators for SD. The United Nations Conference on Environment and Development, for instance, has been working on identifying indicators since 1992, in order to help countries to make informed decisions concerning Sustainable Development.

Two years later, the newly founded Conference on Sustainable Development began developing sets of SD indicators, which are regularly revised to account for new developments and knowledge (World Bank, 2004: 12-13). Other important developers of general SD indicators include the International Institute for Environment and Development and the Organization for Economic Co-operation and Development. Additionally, the World Bank has also been increasingly invested in the identification of general SD indicators. One of the World Bank's proposals is displayed below:

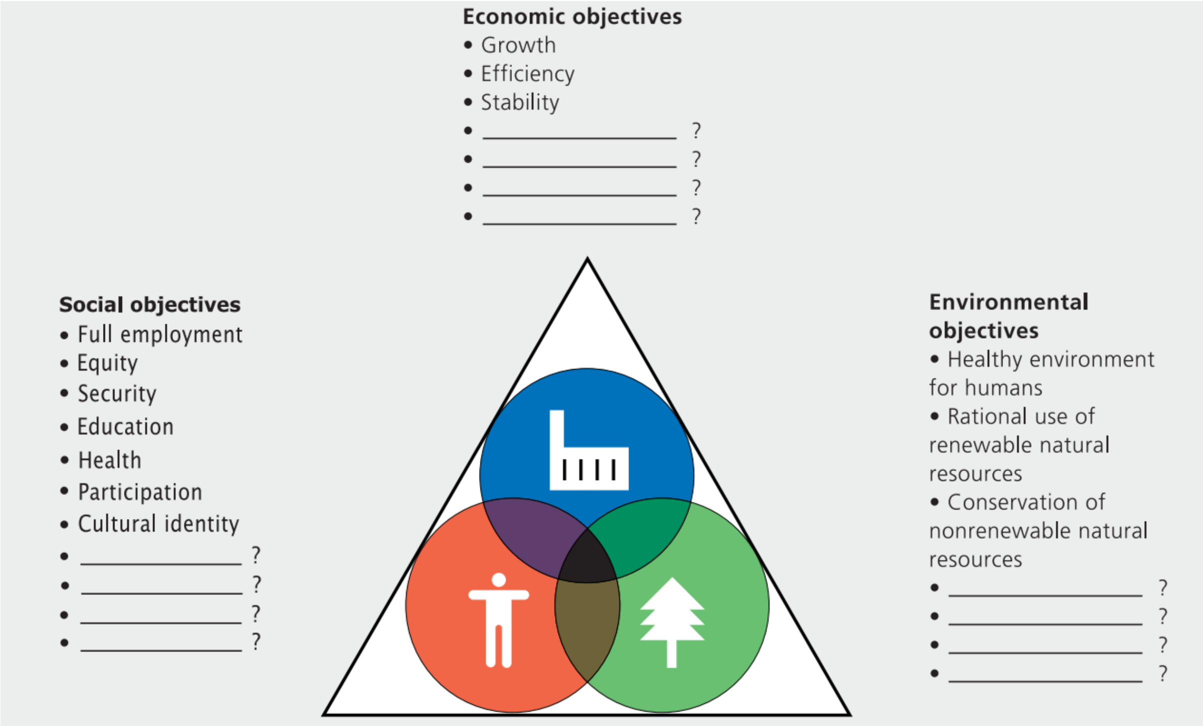

Figure 3.4: World Bank Sustainability Indicators (World Bank, 2004: 10)

As the World Bank framework shows, general sustainability indicators are very broad and lack analytical accuracy. While they are able to provide some general idea of the sustainability performance of a certain region or sector, their utility is limited, because all results are highly abstract and reliant on extremely condensed data sets. Despite the progress in defining indicators of sustainable development over the last decades, difficulties with the application of these indicators remain. For instance, some sustainability analyses assess international phenomena, such as global warming, which cannot always accurately be traced down to a specific source and thereby makes indicator identification very complicated. Moreover, these frameworks typically do not provide a clear methodology on how to weight, correlate and evaluate the indicators. For these reasons, general sustainability indicators have to be considered primarily as a tool to raise awareness for sustainability and improve general willingness of policymakers to implement and improve "green" processes and mechanisms (Chan, 2004: 6).

It is also for this reason, those SD assessments which aim to produce tangible results, concentrate on smaller scale projects where the availability of specific data is very high, e.g. because it can be obtained directly from the source is.[5]

[5] The lack of commonly agreed upon standards is a persistent issues in the field of Sustainable Development and is also present regarding scale differentiation. Company level assessments for instance are often called "large

3.3 General Approach to Indicators

Indicators for the assessment of power plant sustainability vary mostly along one cleavage line: cause and effect. Some authors, most notably the group of experts that developed the UN IPCC's Special Report on Renewable Energy Sources and Climate Change Mitigation, structure their indicator analysis according to the cause of potential sustainability-relevant effects. Such an analysis concentrates on aspects like the hydrological regimes or reservoir creation and examines their influence on sustainability relevant factors.

The second approach utilizes categories and indicators which analyze results (such as changes in biodiversity or emitted greenhouse gases) as a starting point and further examines the underlying reasons for their occurrence. In fact, most analyses include both types. The mixing of two different methodological approaches, while difficult to identify in this specific case, can nonetheless lead to a lack of methodological precision and blurring of the results' validity. To avoid such issues, this thesis will rely on the effect based approach.

As indicated in the previous sections, assessing sustainability requires very different approaches and indicators, depending on the scale, technologies and goals involved. As a general guideline, sustainability assessments will provide less specific and detailed results, the larger the scale of the assessment is. Chapter 2 has shown that there are no studies comparable to this one, which could be used as guidance regarding indicator identification and selection. In order to achieve a balance between meeting the scale of this paper's assessment and aiming for a high analytical accuracy, it is necessary to develop this paper's set of indicators from scratch.

While the indicators are *inspired* from a large amount of sources and other assessments (the most important of which are briefly discussed below), their selection, combination and associated parameters were originally developed by the author in order to achieve the aforementioned balance.

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scale" (see for instance Müller et al., 2013 or Huber and Prammer, 2013). For the purpose of this paper, such assessments are regarded as small scale projects.

One of the frameworks that serve as a foundation for this paper’s selection of indicators is the Gold Standard (GS) framework. The GS is a widely recognized approach for analyzing SD projects (The Gold Standard Foundation, 2011a). It is supported by various sustainable energy movements (The Gold Standard Foundation, 2011b) and has its own technological advisory board, guaranteeing that required technological and analytical expertise is available. The GS analytical framework features twelve indicators, which consist of five environmental, four social and three economic ones, as well as one technological. Each of those indicators also comprises several parameters (The Gold Standard Foundation, 2012, 2-7). The Gold Standard is not exclusively aimed towards sustainability assessment; in their framework it is also used as an analytical tool to assess general performance. However, due to its interdisciplinary approach, it can serve as a useful guidance and foundation in order to develop indicators for this paper’s sustainability assessment.

The second and arguably most sophisticated and recognized comprehensive framework currently available is the one provided by the United Nation’s Intergovernmental Panel on Climate Change’s Special Report on Renewable Energy and Climate Change Mitigation. As a result, the report provides a large amount of approaches and indicators which can be used to assess sustainability on various scales. The indicators were significantly influenced by research of the International Energy Agency (IEA). In particular, the hydropower indicators were produced under the IEA Implementing Agreement on Hydropower Technologies between 1996 and 2006, in cooperation with private agencies, governmental institutions, universities, research institutions and other international organizations (Intergovernmental Panel on Climate Change, 2012: 463). The indicators are based on over 200 case studies, involving experts from 16 countries and provide a decently comprehensive overview regarding social, economic and environmental issues related to hydropower (Intergovernmental Panel on Climate Change, 2012: 463).

The third major framework utilized as a basis for this paper is the *Integrative Dam Assessment Model* (IDAM) (Kibler et al., 2012: 5-21), which has already been discussed in chapter 2. It is particularly suitable due to its highly structured approach and as it has been applied to the East Asian region before.

In addition to these three major frameworks, further guidance for the development of this paper’s indicators comes from the World Commission on Dams (WCD) contributing papers, specifically, *Social Impacts of Large Dams: The China Case,* by Lubiao Zhang from the Chinese Academy of Agricultural Sciences (Zhang, 1999).

It has to be noted that factors which are mainly site specific are generally not included in the analysis, because they would not be applicable to an assessment of hydroelectric energy generation at a country scale. However, exceptions can occur if site specific factors are of such magnitude, that they exert a noteworthy influence on a countrywide level (e.g. discussion of the Three Gorges Dam’s (TGD) impact in chapter 4.1.2) or if the research suggests that they are exemplary for the whole country (e.g. the case studies in chapter 4.3.2 and 4.3.3)

The following section will discuss each of the indicators utilized in this paper, as well as their associated parameters in the following fashion:

- What aspects does the indicator cover and why is it relevant for this assessment?
- How is it measured
- What constitutes positive or negative sustainability performance in regards to these parameters?

As the indicators have varying amounts of specific parameters it is necessary to handle parameters in a unified way, in order to avoid distorting the objectivity of the assessments results. According to the concept of sustainability, each pillar, and by extension, each indicator has to be considered equal. Accordingly, the only consequent way to treat various parameters when assessing an indicator is to treat those parameters equal as well.

3.4 Economic Indicators

3.4.1 Generation Efficiency

Explanation and Relevance

The financial weight of constructing and operating power plants varies significantly according to the type of energy, scale or utilized technology. For hydropower (and most other renewable energies) additional factors, such as topography, geological conditions, etc. are of relevance as well. The concept of Levelized Cost of Energy is the most sophisticated and frequently used way to assess the efficiency of any type of energy generation on a cost over lifetime scale (Intergovernmental Panel on Climate Change, 2012: 1002). LCOE refers to the cost that one unit of energy (usually measured in USD/kWh) has to be in order to break even with all occurring costs (planning, construction, maintenance, operation, interest payments etc.) over the whole average lifetime of a power plant. Any retail price higher than the LCOE of a specific plant will therefore be net profit. Consequently, the lower the LCOE of a power plant is, the higher is its relative generation efficiency (Kost et al., 2012: 8-9). Therefore, LCOE can serve as a useful tool to compare hydropower efficiency not only between two countries, but potentially also with other energy types. This approach is mostly used for the comparison of different energy technologies in the literature, but can also be utilized to evaluate the performance of the same technology under different geographical conditions as done in this paper.

Assessment Approach

LCOE is a type of aggregate data that is based on several parameters: Installed capital cost, capacity factor, economic life, operation and maintenance costs as well as cost of capital. All of these parameters will be assessed for both countries, as far as they are available, in order to give a comprehensive overview. For the assessment however, only the actual LCOE value will be taken into account, as it is the combination of all parameters, rendering the individual evaluations redundant.

Evaluation

Evaluating LCOE is simple: the lower the value, the more cost-efficient energy is generated, the better the performance. The aggregated value of this indicator will be compared to LCOE values of other countries in order to rank and evaluate China's and Japan's performance on a worldwide average.

3.4.2 Inland Water Transport and Navigation

Explanation and Relevance

This indicator will assess the effects of hydropower development on the internal shipping industry in China and Japan. Dams and reservoirs can significantly improve shipping, e.g. by making a river more navigable through backwater. On the other hand, however, they can also encumber it: a dam without a ship lift is usually an insurmountable obstacle for ships.

Inland Water Transport (IWT) is a significant part of the Chinese and Japanese national economy. Not only does it contribute to general creation of value, but it is also of great infrastructural importance, e.g. to supply regions that are difficult to access by other means (e.g. road or rail) with resources in a cost-efficient manner (Ling, 2006).

Assessment Approach

The characteristics of a country's river system are the most important factor when assessing the impact of hydropower plants on shipping and navigation. Accordingly, the general geographic situation and its relation to shipping for both countries will be assessed first. On that basis, the impact of hydropower stations will be examined, placing special emphasis on the impact of backwater development as a result of hydropower reservoirs.

Evaluation

Due to the scarcity of statistical data, the rating of this indicator will be based on a single parameter: the overall effect that hydropower exerts on the respective shipping sector.

Accordingly, a positive effect will be considered as sustainable performance, while negative performance is constituted by a negative impact of the hydropower sector, i.e. the impediment of the respective country's IWT.

3.4.3 Irrigation

Explanation and Relevance

Irrigation aims to assess the economic impact that hydropower stations exert by providing water supply to agricultural systems. Irrigation is an integral part of every agricultural sector and particularly important in Asia, due to the high water requirements of rice cultivation.[6] Irrigation includes direct supply, i.e. water directly provided by dams, as well as indirect water supply, which refers to the transfer of water through other means, as long as the water provided would not be available without the dam. The latter can, for instance, occur when additional water is discharged and utilized by irrigation systems further downstream (e.g. in cases where the river acts as an intermediary transport mechanism).

Assessment Approach

This indicator will be based on a single parameter: The amount of water supplied through hydropower. The analysis will be based primarily on statistical data provided by the World Commission on Dams and the United Nation's Food and Agricultural Organization (FAO). Those values will be compared to the averages of other Asian countries, which will provide better comparability due to a more similar environmental background and challenges (e.g. the aforementioned water intensity). In addition, the Asian nations have a smaller overall variance regarding their irrigation related hydropower statistics, which offers a more refined and graduated baseline for comparison (World Commission on Dams, 2000: 13).

[6] The production of 1kg of rice requires 5000 liters of water, which is approximately twice the amount necessary to produce corn, rendering rice production the most water intense staple food (Papademetriou, 2000).

Evaluation

A positive sustainability performance for this indicator will be achieved by exceeding the average values of hydropower contribution to irrigation in Asian countries. Accordingly, should the contribution in China or Japan be lower than the Asian average, the indicator will be rated as unsustainable for that country.

3.5 Ecological Indicators

3.5.1 Greenhouse Gas (GHG) Emissions

Explanation and Relevance

Greenhouse Gas Emissions (GHG) contribute significantly to global warming and are a core issue, not only for sustainability, but also for climate change mitigation. These emissions are not limited to Carbon Dioxide (CO_2), but include over 50 other gases. The most influential among them (in general, as well as for hydropower in particular) are Methane (CH_4) and Nitrous Oxide (N_2O) (Intergovernmental Panel on Climate Change, 2007: 212-213). To keep the analysis transparent, this paper will not address those gases individually, but use their CO_2 equivalent (CO_2eq) instead. The CO2eq describes the amount of CO_2 necessary to achieve a similar impact on the atmosphere for any given Greenhouse Gas over a certain period. Over 100 years (the most commonly used timeframe), the CO_2eq of Methane is 25, while the CO2eq of Nitrous oxide is 298 (Intergovernmental Panel on Climate Change, 2007: 212-213). This allows for easier comparison and evaluation.

Addressing this indicator is particularly important because of the common believe that hydropower is a GHG–neutral energy source (e.g. Inoue and Shiraishi, 2010: 79). Even if emissions are taken into account in life cycle assessments, they mostly refer only to GHG emitted during the construction process. Hydropower plants, however, do emit the highest amount of GHG during the early phase of their operational lifetime (Barros et al, 2011: 594), because of the high amount of biological matter that is present in most reservoir areas prior to the initial impoundment. During the first years of operation, this stock of biological matter intensifies the normal biological processes within a reservoir (or any other standing water body). After several years, the bio-matter supply is used up, resulting in the leveling out of the reservoir's GHG emissions. Although these processes constitute "natural" GHG emission, the inducing water body was man-made and this paper is therefore attributing any resulting emissions to the respective power plant (Mendonca et al., 2012: 59-60).

While the argument can be raised, that in certain cases a preexisting water body constitutes the "core" of the reservoir, and therefore not all of the resulting emissions can be attributed to the respective power plant, the analysis will try to show that the amount of "preexisting" emissions is negligible compared to the emissions generated by the transformation of said water body into a reservoir (Mendonca et al., 2012: 56-60).

Assessment Approach

Unfortunately, the relevant data for this indicator (i.e. GHG emissions of hydropower plants and reservoirs on a national scale) are not available as of yet. The very fact that reservoirs emit significant amounts of GHG was just recently discovered (Mendonca et al., 2012: 55-60) and comprehensive measurements have not been conducted yet. Therefore, this indicator has to be assessed through an indirect approach, which primarily relies on information about how GHG emissions generally develop in relation to the age and geographical location of the respective reservoirs. Based on this information and general data about hydropower development in each country, it is possible to assess GHG performance and trends in general, even without actual emission data.

Evaluation

Sustainable performance in regards to GHG emissions is equal to low emissions, while unsustainable performance is constituted by high emissions. Due to the lack of available statistical data, the evaluation cannot be based on a baseline of absolute numbers (e.g. international average of GHG emissions per kW/h of electricity generated). Instead, the general impact of recently discovered reservoir emissions will be assessed. If it is possible to link geographical characteristics of China and Japan with a significant emission of GHG, the indicator will be ranked unsustainable. If the data indicate non-significant emissions, it will be rated as sustainable.

3.5.2 Biodiversity

Explanation and Relevance

Hydropower development modifies existing terrestrial and aquatic habitats massively and irreversibly. This causes serious issues to flora and fauna, such as habitat alteration, species mortality, injury, disturbance, etc. The resulting loss of biodiversity (which mostly affects aquatic life) (International Centre for Environmental Management, 2010: 17-20; Rai, 2008: 22-25) is one of the most controversial issues in regards to every new hydropower project. The impacts are not only limited to the immediate proximity of the dam, they can also be exerted hundreds of kilometres further downstream, e.g. through changes to the rivers flow pattern which negatively impacts aquatic species. If endemic species are affected, the loss of *Biodiversity* is particularly severe, as it not only constitutes a quantitative loss that bears the potential for recovery, but an irretrievable loss in qualitative biodiversity (International Centre for Environmental Management, 2010: 17-20).

Assessment Approach

As a first step it will be assessed what kind of impacts are generated by hydropower plants and how severely various types of animals and plants are affected. For this part, general and non-country specific literature about hydropower impacts will be utilized. The second step is to analyse developments in species' numbers that are affected by hydropower projects. In this regard the focus lies on endemic species. While the loss of any life is undeniably a negative occurrence, the extinction of species endemic to a certain region means an irreversible decline in total worldwide biodiversity. Due to the lack of available statistical data, the assessment of biodiversity will follow an indirect approach.

Evaluation

As the loss of biodiversity affects the entirety of the earth’s ecosystem, it is justified to base the assessment on a comparison of absolute numbers (e.g. of species endangered due to hydropower in a specific country) and not account for the major differences in scale between Japan and China by relying on relative numbers.

While it is not possible to determine specific empirical values, the analysis will enable the identification of clear trends, which will be used to evaluate biodiversity impacts in China and Japan. A sustainable performance in the category *Biodiversity Impact* is to not cause the extinction of whole populations or even species. A negative *Biodiversity Impact* occurs if hydropower development causes effects resulting in significant loss of endemic species.

3.5.3 Sedimentation

Explanation and Relevance

Sedimentation assesses the impact of this natural effect on the functionality of hydropower plants. The creation of a reservoir changes the hydraulic and sediment transport characteristics of a river - the sediment load is partially trapped within the storage and can therefore not be transported further downstream. This causes not only a lack of sediment material in downstream areas, but also negatively impacts the hydropower plant itself: The accumulation of sediment causes a reduction of generation performance, and can, depending on the sediment composition, even damage electromechanical machinery (Xu, 2002: 154-163).

Assessment Approach

Firstly, the general sediment load in China and Japan will be examined. The geological situation of both countries will be discussed according to its importance for the respective amount and composition of sediment on the basis of general literature. Following this discussion, both countries will be compared in regards to the amount of sediment they are exposed to on an annual level and how this relates to the loss of their respective reservoir capacity.

Finally, the impact of sediment trapping and the resulting erosion on downstream areas will be discussed. However, due to a lack of comprehensive and reliable data, the latter will not be included in the evaluation of the indicator.

Evaluation

The impact of *Sedimentation* is based on one parameter: the amount of hydropower storage lost annually due to sedimentation and the type of sediment. In regards to the annual capacity loss, a positive performance would be achieved by a country when its sediment yield is below the international average, a negative performance if it exceeds the international average. Additionally, this chapter will include an examination of the sediment composition, which can exert significant influence on the costs associated with hydropower plant operation. Sediment with a fine composition does not harm dams, a coarse composition, e.g. with a high share of rock particles, will damage turbines and other electromechanical machinery in a dam, leading to downtimes and higher maintenance costs (Committee on Cost Savings in Dams, 2008: 23). While sediment composition is an important part of this issue, it will not be included in the evaluation, because its influence on hydropower costs will already be addressed by the discussion of hydropower LCOE in chapter 4.1.1. Including it in the sedimentation examination as well would violate the principle of treating parameters, indicators and pillars equal.

3.6 Social Indicators

3.6.1 Safety

Explanation and Relevance

Safety is one of the indicators that convey the idea of Sustainable Development the most. The indicator assesses the ways and degree to which hydropower can potentially endanger human lives and infrastructure as well as the security measures taken to reduce the likelihood of such scenarios. The large amounts of water stored in many reservoirs hold enough destructive potential to create immense damage in the downstream area in case of a dam breach (Chen, 2004: 2). Accordingly, safety measures to prevent dam failure are a necessary prerequisite to ensure that not only the hydropower facilities remain functional, but also that the material and physical safety of people in the plant's proximity is not endangered. In addition, Reservoir Induced Seismicity (RIS),[7] which can result from hydropower development in areas of tectonic activity, can cause earthquakes and thereby negatively impact public safety.

Assessment Approach

It is not viable to analyze safety data of every Chinese and Japanese reservoir dam individually. Therefore, the assessment of this indicator follows a different approach.

Firstly, the legal regulations regarding dam safety and its implementation and monitoring will be assessed in order to gain an overview of what priority this topic is given by the respective governments and operators. This includes analyzing the intensity and frequency of inspections, as well as where the final responsibility for safety measures lies. The second step is to analyze the risk environment in both countries in order to assess what kind of potential damage has to be expected. To this end, the vulnerability to earthquakes is especially important, because it is the only frequently occurring event that possesses the destructive potential to destroy large scale hydropower dams (Wieland, 2008: 1-2). The geographical location of epicenters in relation to the location of major dams will be assessed as well as the actual safety performance of dams in both countries, by referring to the annual dam breach ratio, as well as the performance over the two major earthquakes that hit China and Japan in

[7] RIS is also commonly referred to as Reservoir Triggered Seismicity (RTS).

2008 and 2011 respectively. Lastly, the relevance of RIS and its impact on safety will be examined.

Evaluation

As shown, this indicator has **three parameters**: regulatory framework, the exposure to (natural) risks and the respective dam safety performance, as well as the RIS related risks.

In regard to the framework, a sustainable performance would be attained in case of a comprehensive regulatory legislation and its timely and sufficiently complete implementation and execution. The exposure to natural earthquake risks can be considered sustainable if it is very low (based on an international comparison), and there are no major issues regarding the safety performance of dams in China and Japan (e.g. dam breaches) in recent history. Regarding the relevance of reservoir induced seismicity, a sustainable performance would be attained if the respective hydropower sectors do not cause any noteworthy safety issues due to RIS effects.

3.6.2 Community Engagement

Explanation and Relevance

Resident communities are usually most affected by negative impacts (e.g. loss of property, change of socio-economic environment, etc.) (World Commission on Dams, 2000: 108-109). *Community Engagement* analyzes if and to what degree communities affected by hydropower development are included in the project development process. It also examines the capacity of those communities to enforce their interests if necessary, (e.g. in conflict cases where the dam developer does not want to include affected populations or account for their needs at all). Hydropower developer also stand to lose from a conflict situation, as it can lead to various problems, including, but not limited to negative publicity, construction delays, increased costs and even the cancellation of the project. Therefore, it is important to address the requirements and opinions of affected resident communities, in order to reduce tensions and prevent the development of conflict situations, which are not desirable for any involved party.

Assessment Approach

Any assessment of *Community Engagement* or similar indicators, will necessarily suffer from the dominance of *Involuntary Displacement* among publications regarding social impacts of hydropower (World Commission on Dams, 2000; Scudder, 2005). There are no comprehensive, nationwide statistics available regarding *Community Engagement*. For this reason, the assessment has to rely on the analysis of exemplary case studies.

Another factor making this assessment difficult is the trade-off inherent to the indicator: community rights on the one hand and viability of a project for a hydropower developer on the other hand. Not considering needs and requirements of affected communities can lead to significant resistance to the dam construction. However, a situation in which local resistance is too easily appeased can also cause the cancellation of dam projects, which would impede hydropower development in general, resulting in no (Sustainable) Development of hydropower at all.

However, since this paper takes a nation-wide approach, it is important to note that a hydropower project that was cancelled due to civil resistance would most likely not be completely disregarded, but rather developed in another area with more favorable conditions. Moreover, the basic principle of Sustainable Development (the concordant pillar approach) implies that sustainability can only be achieved if a project is not developed against the majority will of the affected population. Therefore, in the context of this work, social acceptance will be considered sustainable only if it prioritizes the demands and needs of the local population, regardless of the outcome for plant construction. Accordingly, for this indicator there is only a **single parameter**: How effectively can affected communities influence hydropower development in their proximity.

Evaluation

Positive performance regarding *Community Engagement* is achieved when the needs and requirements of communities, which are negatively affected by hydropower development, are prioritized during the project decision making. Accordingly, the ultima ratio in conflict cases has to be the cancellation of the project. If projects are repeatedly developed against ongoing resistance of the affected population’s majority, the indicator has to be rated as not sustainable.

3.6.3 Involuntary Displacement

Explanation and Relevance

Dam construction unavoidably results in the loss of land due to submersion and development of related infrastructure projects. *Involuntary Displacement* refers to the physical displacement of citizens against their will, made necessary by these land losses. It is the most sensitive social issue connected to a hydropower project (World Commission on Dams, 2000; Scudder, 2005). Because *Involuntary Displacement* often confronts the victims with the complete loss of their livelihood foundation, including employment and housing, it has the potential to cause significant social tensions, which occasionally even lead to violent conflict between the affected population and law enforcement units (see also chapter 4.3.2).

Assessment Approach

The assessment of this indicator will be based on **three parameters:** Firstly, statistics, as available, in order to rank the number of people involuntary displaced in China and Japan in relation to other countries. Secondly, the legal foundation for involuntary displacement and expropriation will be examined. Finally, case studies will be utilized in order to assess how the replacement process has been carried out in relation to the legal standards set by the countries themselves, whether the livelihoods and standard of living has improved or worsened for resettlers and in which way host communities were affected.

Evaluation

Good practice in regards to involuntary displacement is constituted by low numbers of involuntary displacement cases (based on international averages), a comprehensive legal framework that ensures compensation for resettlers sufficient enough to guarantee that livelihood quality (measured primarily by the financial and employment situation) is not decreased due to the resettlement. In addition, the implementation of the legal framework has to be effective, e.g. embezzlement and corruption among the conducting administration must not be a common problem.

3.7 Evaluation

The assessment of sustainability performance of hydropower in China and Japan will be conducted according to the priorities set in the previous chapters. The final rating is constituted of three different layers: indicators, pillars and overall.

Indicators are assessed based on their individual parameters, which can be either sustainable or unsustainable and are treated equally in order to comply with the concept of SD (see chapter 3.3). The rating of indicators will be based on a simple majority of their parameters, meaning that two positive parameters would outweigh one negative parameter, thereby constituting a sustainable performance regarding this indicator. In case there are as many positive as negative parameters, the indicator will be rated as exerting neither clearly positive nor negative effects. Accordingly, the indicators will be assessed on the basis of three possible outcomes: sustainable performance, non-influential and unsustainable performance. To make these results quantifiable and increase the analytical accuracy, each performance level is assigned a numerical value (+1, 0 and -1).

Rating	Performance Assessment
1	**Sustainable Performance**
0	**Non-Influential**
-1	**Unsustainable Performance**

Table 3.4: Indicator Performance Rating

A similar approach is applied to the evaluation of the three pillars. If there are more indicators with a positive performance, the pillar will be considered sustainable, and vice versa. The assessment of the average performance of each pillar will be aggregated in accordance to table 3.5. On this basis it will not only be possible to assess whether or not hydropower is sustainable in China and Japan, but also to show in which areas and to what extent the performance differs between China and Japan.

The previous chapters have shown that the concept of Sustainable Development is a binary one: a project can only be sustainable or unsustainable; there is no "in-between". In addition, for a project to be sustainable, all pillars – economy, society and ecology - have to be sustainable. However, to answer this paper's research question, i.e. assessing the effectiveness of hydropower in the Chinese and Japanese energy sector, these paradigms would be detrimental, as they would only lead to an evaluation of "sustainable" or "not sustainable", but would not allow a comparative evaluation of the *degree* of effectiveness. Therefore, for the concluding evaluation, the overall average value of all indicators will be utilized to evaluate how the two countries perform in comparison (see table 3.6).

Pillar	Indicator	China		Japan	
		Parameter	Rating	Parameter	Rating
Social	Community Engagement				
	Involuntary Displacement				
	Safety				
	Average				
Economic	Generation Efficiency				
	IWT and Navigation				
	Irrigation				
	Average				
Environmental	GHG Emissions				
	Biodiversity				
	Sedimentation				
	Average				
Overall Average					

Table 3.6: Assessment Rating Template

4. Application

4.1 Economic Indicators

4.1.1 Generation Efficiency

The Levelized Cost of Energy is the most comprehensive factor available to determine to generation efficiency of any given power plant. LCOE displays the output price required to achieve a break-even result between revenue generated and investment necessary over the course of an expected average lifetime for a power plant. Any price higher than the LCOE would therefore generate pure net profit and thus represent the competitiveness of the respective power plant (Intergovernmental Panel on Climate Change, 2012: 976).

In case of hydropower, it is particularly useful, because the highly asymmetrical nature of the hydropower cost structure (with very low relative costs for operation and maintenance) makes it superficially seem very cost efficient, which is not necessarily the case, due to the enormous construction costs involved in a hydropower project when compared to other power plant types. LCOE helps to unify these factors into a comprehensive and sound number to reliably determine the performance of hydropower compared to other energy sources.

This chapter will firstly analyze the LCOE of hydropower in comparison to other renewable energy sources, to assess its overall sustainability in economic terms. Afterwards, the aforementioned factors will be analyzed one by one in regards to their specific values in China and Japan.

While there are a few different formulas to assess the LCOE, the values in this work are based on calculations of the most commonly used one which is also applied for calculations of various renowned institutions such as IRENA and IPCC (International Renewable Energy Agency, 2012: 27-30; Intergovernmental Panel on Climate Change, 2012: 976):

$$C_{Lev} = \frac{\sum_{j=0}^{n} \frac{Expenses_j}{(1+i)^j}}{\sum_{j=0}^{n} \frac{Quantities_j}{(1+i)^j}}$$

C_{lev} = levelized cost
n = lifetime of the project
i = discount rate
Expenses = investment, O&M costs, fuel costs
Quantities = electricity generation

There are several factors that exert a high impact on the result of a LCOE assessment, which will be discussed in detail below (International Renewable Energy Agency, 2012: 27):

- Installed capital cost (total investment cost)
- Capacity factor
- Economic life
- Operation and maintenance costs
- Cost of capital

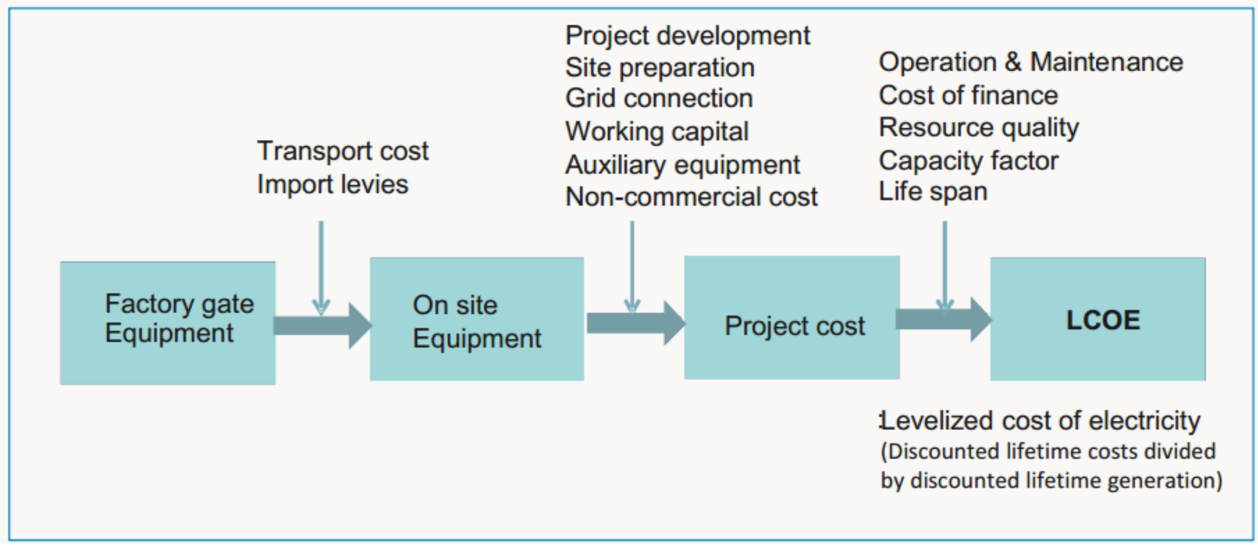
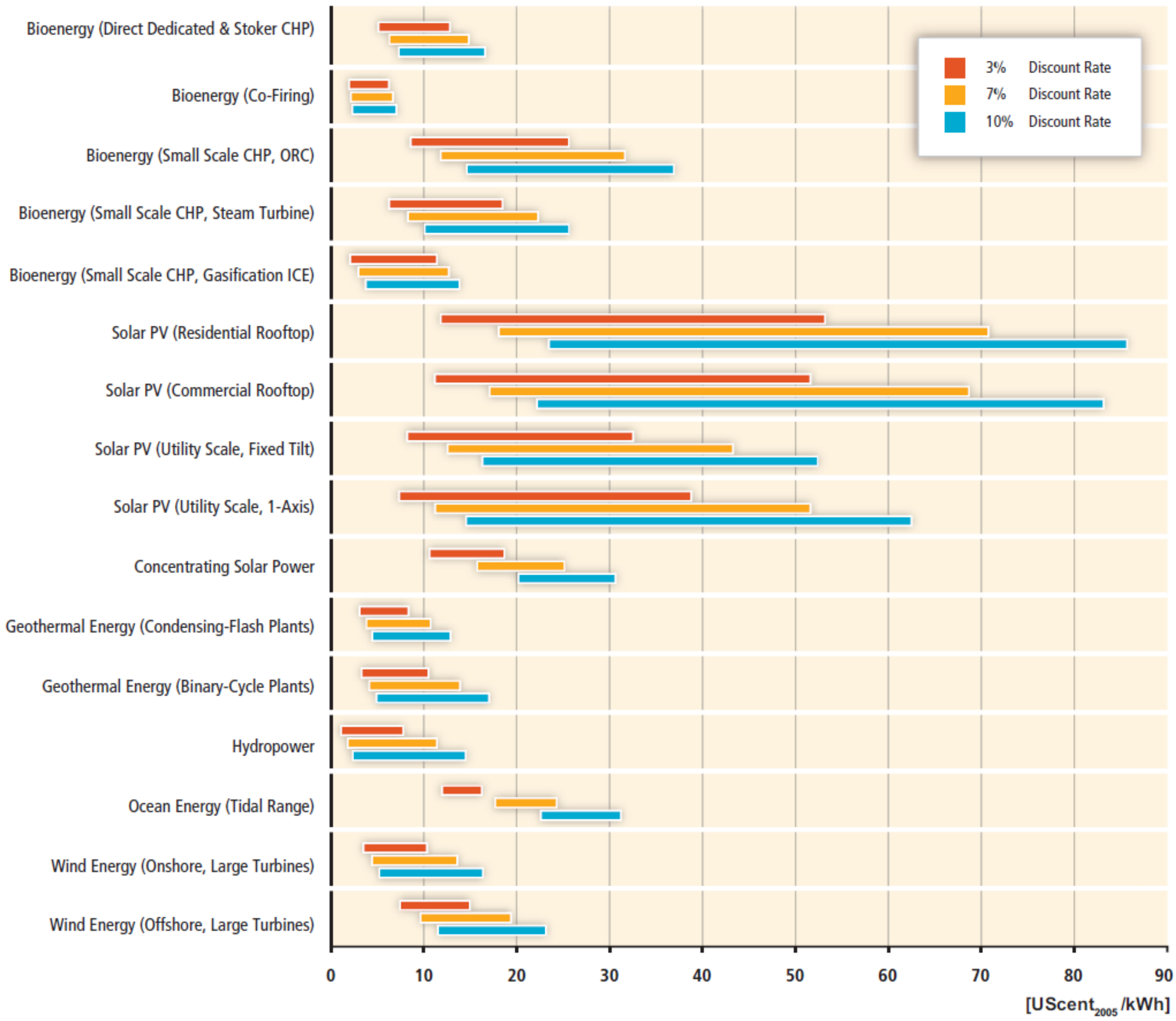


Figure 4.1: LCOE – Included Parameters (International Renewable Energy Agency, 2012: 2)

LCOE Comparison

According to the ICCP, hydropower has - on average - one of the lowest LCOE values among renewable energies. With a LCOE of 0.01 to 0.07, 0.11 and 0.14 USD/kWh (for capital costs of 3%, 7% and 10% respectively) it is only second to Co-Firing Bioenergy, a method which utilizes traditional fuels in addition to biomass (see graph 4.17; Intergovernmental Panel on Climate Change, 2012: 844).



Graph 4.2: LCOE by Energy Type (Intergovernmental Panel on Climate Change, 2012: 844)

Installed Capital Cost

The installed capital cost refers to the complete amount of money invested during the construction of a hydropower plant, including all related infrastructure and service operations. It will vary significantly depending on the cost of local work and materials (International Renewable Energy Agency, 2012: 2-3). The cost of a hydropower plant stems from 2 major sources. The first one is the electromechanical equipment, which includes turbines, monitoring and controlling equipment etc. These objects are bought on the world market and as a result their price tends to be similar no matter where the power plant in question is being built (Intergovernmental Panel on Climate Change, 2012: 457). The second cost factor is the actual construction, which for the most part includes worker wages, resettlement costs and compensations, construction of the reservoir, related infrastructure and resettlement facilities, as well as normal building materials such as cement. This second set of cost factors is region specific. Workers for the most part receive the average local wages; most basic building materials are sold by regional companies for average regional prices and so on. Consequently, this share of the overall construction budget is highly dependent on the local cost structure (Intergovernmental Panel on Climate Change, 2012: 457).

According to the IPCC *Special Report on Renewable Energy and Climate Change Mitigation* the two cost factors are at an equal cost influence when the power plants generation capacity is at approximate 5 MW. If the plant has a higher capacity, the relative portion of the second cost factor set exponentially increases due to the asymmetrically higher amount of construction needed compared to additional electromechanical machinery (Intergovernmental Panel on Climate Change, 2012: 477; International Renewable Energy Agency, 2012: 21).

In large scale power plants, the electromechanical costs are almost negligible for the overall budget. For this reason, countries with relatively weak or under-developed economies and therefore lower average wages have less installed capital cost for similar generation capacity than countries with strong economies and higher average wages. Thus, countries with weak economies typically have a lower average LCOE and thereby a higher economic sustainability (Intergovernmental Panel on Climate Change, 2012: 477).

The worldwide average fluctuations of large scale hydropower plants range typically between USD 1 000/kW to around USD 3 500/kW. For **China,** the average installed capital cost ranges between 800USD/Kwh and 1600 USD/kwh. While the low end is similar to that of many other countries, such as India (700USD/kwh), the US (750 USD/kwh) or the European Union (1100 USD/kwh), the upper end of the Chinese cost is the lowest among any major hydropower producing country. The distance to the upper cost level of developed countries such as the EU (4800 USD/kwh), the US (3800 USD/kwh) or Canada (4600 USD/kwh) is particularly high. (International Renewable Energy Agency, 2012: 19-20). As a result of the very small variance between lower and upper end costs, the Chinese average installed capital cost is very low and the accuracy of cost predictions for new projects is better than in cases of large variance (International Renewable Energy Agency, 2012: 19).

While there are no specific data available for the installed capital cost of hydropower in **Japan**, the fact that all developed countries feature very high average installed capital costs, the high average installed capital cost of Asian countries and the fact that China has the lowest average capital cost of all countries with available data, it is reasonable to assume that the Japanese installed capital cost is higher than the Chinese.

It is important to note that there is another factor that influences the installed capacity: the decommissioning cost of the dam, since it is also construction related. However, even if hydropower is a very mature and experienced technology, with its high lifetime expectancy, there is a severe lack of data (Intergovernmental Panel on Climate Change, 2012: 481). Therefore, decommissioning costs are not included in the LCOE costs used for this work.

Capacity Factor

The capacity factor is a constructed value to assess the amount of generation efficiency a power plant can employ. It is the ratio of a plant's actual output during a certain time period to its potential output if indefinite operation at full nameplate capacity was possible. The higher the value, the more efficient energy potentials are utilized and transformed into electricity. For the calculation of the capacity factor, the total amount of energy the hydropower plant has produced over a certain time period is divided by the amount of energy it would have produced at full capacity (Intergovernmental Panel on Climate Change, 2012: 445, 481-483).

The following example of the Three Gorges Dam illustrates this calculation. With a total installed capacity of 18,200 MW, multiplied by 24 (hours) and 365 (days), the plant could achieve an annual output of 159,432,000 MW/h if running at 100% efficiency. Since the total generation of the plant within one year amounted to 84,700,000 MW/h, the plant operates at an efficiency grade (capacity factor) of 54.47% (China Three Gorges Corporation, 2010).

$$\frac{84{,}700{,}000\ \text{MW/h}}{(365\ \text{days}) \times (24\text{h/day}) \times (18{,}200\ \text{MW})} = 0.5447 \approx 55\%$$

The capacity factor is influenced by various parameters, such as the hydraulic head (the energy per unit mass of water, which is mainly based on the height difference through which the water falls and the velocity at which the water does so). Moreover, the capacity factor of hydropower plants can vary significantly. These differences are mainly due to geographical features and are rather unique to renewable energy sources, while capacity factors of traditional combustion based fuels are mostly the same with slight variations according to the quality of the fuel. A country with generally steep rivers, such as Japan, will have a higher capacity factor than a country with shallow rivers, which in turn significantly affects the outcome of a LCOE assessment (Intergovernmental Panel on Climate Change, 2012: 445, 452, 481).

While the difference between Japan and China is not very large, Japan has a slightly higher capacity factor of 45% (Inoue and Shiraishi, 2010: 87), mostly due to the fact that its rivers are relatively short and thus achieve a higher hydraulic head. China averages a capacity factor of 42% (Intergovernmental Panel on Climate Change, 2012: 481). Considering that, worldwide, the range of capacity factors lies between 25% and 90% for large scale hydropower plants, the difference between China and Japan is negligible (International Renewable Energy Agency, 2012: 1).

Economic Life

Economic life refers to the average lifetime of a power plant. In regards to hydropower this is mainly influenced by sedimentation. On the one hand, sediment loads can shut a hydropower plant down completely if the amount of trapped sediment is too high. On the other hand, certain types of sediment can damage the electromechanical equipment such as turbines, thus reducing the lifetime expectancy (Intergovernmental Panel on Climate Change, 2012: 454).[8]

Operational and Maintenance (O&M) Cost

The operational and maintenance costs depend mainly on the local wage levels and are therefore subject to significant regional differences. In that regard, they can be treated similar to the construction costs. This is also reflected in current research, which usually values the O&M costs as a percentile rate of the initial construction costs. The range for large scale hydropower usually lies between 2% and 2.5% of the construction costs (International Renewable Energy Agency, 2012: i).

In addition to that, it can be assumed that Japan has higher O&M costs due to the nature of Japanese sediment load, which, while of lesser volume than in China, has a higher share of rock particles, which tend to damage turbines and similar equipment. These factors increase O&M costs notably, although it is currently unclear by how much of a margin (Intergovernmental Panel on Climate Change, 2012: 454).

[8] For a detailed assessment of the impact of sediment types, see chapter 4.2.2.

Cost of Capital

As the general LCOE introduction and graph 4.17 have already shown, the cost of capital does play a major role in determining LCOE. The cost of capital refers to the cost of a company's debt and equity, and can be considered the minimum return that investors expect for providing capital. As such, a key factor that determines the cost of capital is risk. A project with greater risk (e.g. of non‑payment of electricity sales, currency risk, inflation risk, etc.) will require a higher rate of return (International Renewable Energy Agency, 2013: 19-20).

Unfortunately, there are no reliable data on the cost of capital in regards to hydropower development in China and Japan. It could be assumed that China has a slight edge because of the strong integration of the government through its banks and state owned enterprises, but any judgment based on such general factors and without reliable empiric data would be speculative, which is why the cost of capital will not be assessed here.

Levelized Cost of Energy and Conclusion

The levelized cost of hydropower compared to other sources of renewable energy is highly competitive with only between 0.02 and 0.19 USD/kWh depending on various factors (International Renewable Energy Agency, 2012: i).

The detailed assessment of each factor showed that two out of five factors influencing LCOE cannot be properly assessed with the data available to the author. Among the remaining three factors, two (operational and maintenance costs as well as installed capacity cost) favor the PR China over Japan, while the third one (capacity factor), favors Japan. However, compared to international fluctuations of capacity factor, the difference is so minor that is can be considered negligible. Therefore, it is reasonable to expect China to have a significantly lower hydropower LCOE than Japan.

The LCOE in **China** is comparatively low, ranging from 0.025 to 0.05 USD/kWh. (International Renewable Energy Agency, 2012: 29) This value is similar to the lower end performance of many other countries, including the United States which starts at 0.03 USD/kWh, Canada and Brazil.

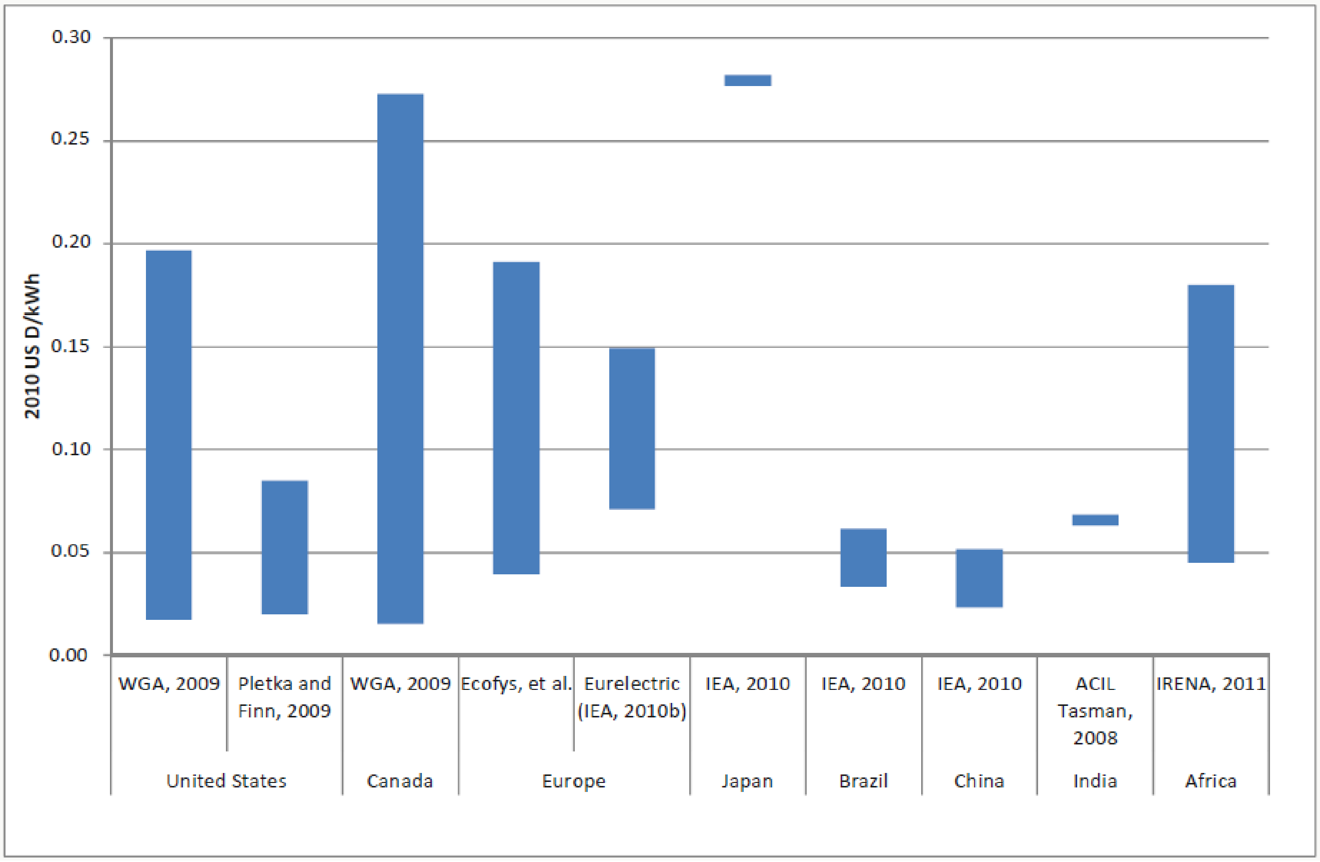


Figure 4.3: LCOE for Hydropower Plants by Country and Region (International Renewable Energy Agency, 2012: 29)

However, with the exception of Brazil, all of these countries scale significantly higher for the upper end of their respective LCOE spectrum, e.g. US with 0.19 USD/kWh and Canada at 0.26 USD/kWh (International Renewable Energy Agency, 2012: 27-29). Due to this cost efficiency, China is considered sustainable in regard to its hydropower LCOE, resulting in a rating of +1.

Japan's hydropower LCOE, on the other hand, suffers from parameters such as high local material costs and wages, maintenance-intense sediment composition, etc. As a result, with an average value of approximately 0.27 USD/kWh (International Renewable Energy Agency, 2012: 29), as well as a very narrow fluctuation range, Japan's LCOE "exceeds" the USA, Canada and the European Union. Compared to China, Japan's LCOE is almost seven times higher (International Renewable Energy Agency, 2012: 27-29). With one of the most expensive hydropower sector in the world, Japan can only be considered as unsustainable in regards to its LCOE, resulting in a rating of -1.

4.1.2 Inland Water Transport and Navigation

Hydropower development impacts a country in many different ways. It can induce major spillover effects that strengthen a region's economy far beyond the location of the dams itself. One of the most influential examples of this is the impact of dams on shipping and navigation. Because it is subject to geographical features of a country, in particular the characteristics of the respective river system, the differences between countries can be very significant (Gleick, 2009b: 140-144).

A reservoir dam is by definition a physical blockade for anything that intends to navigate a river, be it cargo, fish or personal transports. Without further infrastructure, such as ship lifts, the navigation at this part of the river would be impossible, thus impeding a country's Inland Water Transport (IWT) sector. For this reason, the majority of dams are equipped with ship lifts to enable navigation for most vessels. As long as ship lifts are of sufficient capacity, the respective dams do not exert any negative impacts on IWT. On the other hand, dams can also provide benefits, e.g. by making river passages accessible, which otherwise would too dangerous or shallow (Ponseti and López-Pujol, 2006: 158). This effect is caused by the reservoir: The backwater generated by dams can extend to significant lengths, sometimes over several hundred kilometers. This leads to increased water depths and width, which in turn makes the affected river sections more navigable for ships with higher water displacement (Ponseti and López-Pujol, 2006: 158). As a result, larger ships can access more parts of the river, decreasing the cost of transportation and subsequently of all related goods, which can be a major economic stimulus for the affected region (International Commission on Large Dams, 2013b).

Additionally, a strong increase in IWT will also have positive impacts on environmental aspects. Because ships emit less Greenhouse Gases than road- or air-based transport (per amount of transported cargo per distance), the increased efficiency of IWT typically drains a certain share of transport volume away from those less efficient transport options (Gleick, 2009b: 144). However, it is impossible to obtain specific data on this aspect because it is unknown to what degree transport volume shifts between IWT, road, airplane or railway transport can be attributed to increased efficiency in IWT. It is nonetheless a positive impact of dam construction that has to be kept in mind when assessing the issue.

China's Inland Water Transport sector has increased significantly over the last decades. The cargo volume grew by an annual average of 38.6% between 1990 and 2000, with an absolute growth from 100,000 twenty-foot equivalent units (TEU) to 1.88 million TEU, which amounts to roughly 690 million tons of cargo tonnage (United Nations Economic and Social Commission for Asia and the Pacific, 2003: 126-127). In administrative terms, China's IWT sector is divided into 5 areas: the Yangtze River, the Pearl River (珠江), their respective deltaic zones, as well as the Beijing-Hangzhou Grand Canal (京杭大运河) (United Nations Economic and Social Commission for Asia and the Pacific, 2003: 125).

However, the Chinese IWT sector is dominated by the Yangtze River System.[9] Out of China's total of 5,600 navigable rivers with overall length of 119,000 km, the Yangtze and its tributaries comprise almost two thirds: 3,600 rivers and approximately 77,000 km of navigable river distance (United Nations Economic and Social Commission for Asia and the Pacific, 2003: 125). Out of the total 5,800 km of waterways that are navigable for ships with more than 1000 gross register tons, the Yangtze system provides about 2,500 km. While the Yangtze's comprises 64% of China's total navigable waterways and 43% of those navigable by ships larger than 1000 tons, the share of goods transferred through the Yangtze and its tributaries amounts to more than 80% of China's total IWT transport volume (Ponseti and López-Pujol, 2006: 166-167).

In the light of these numbers, the Yangtze is by far the single most important factor for any assessment of China's IWT. As a result, the available data for IWT in China are almost exclusively focused on the Yangtze system. Correspondingly, this paper's assessment of hydropower impact on IWT in China will follow the same approach.

The Yangtze has such a disproportionally high share of IWT, because it is – and always has been – the only cost-effective way of cargo transportation in and to southern China. It therefore holds a key economic position: Chongqing (重庆市), with 28 million citizens the largest municipality in China, receives approximately 90% of its supplies through IWT on the Yangtze (Ponseti and López-Pujol, 2006: 166-167). However, shipping navigation on the Yangtze has not been easy in the past. The river has several dangerous sections, such as Jingjiang (靖江市), where ships are endangered by sandbars, shallow waters and flow instability (Ponseti and López-Pujol, 2006: 162). The most dangerous stretch for large ships

[9] Hereinafter, "Yangtze" is used as a reference to the whole Yangtze River System, including all tributaries as described in this part.

is located between Yichang (宜昌市) and Chongqing, approximately 660 km upstream. This area features 139 dangerous shoals, rapid flow changes and 46 one-way control sections (Ponseti and López-Pujol, 2006: 158).

The Chinese government has made significant efforts to improve the navigability of the Yangtze, in which the construction and upgrading of dams play a major role. One of the largest infrastructure investments in Hunan province (湖南省), amounting to 220 million USD, is mainly concentrated on the development of new hydropower projects with very specific features to improve navigability on the Yangtze (United Nations Economic and Social Commission for Asia and the Pacific, 2003: 125-126). Large dams can improve navigability of rivers in several ways: By providing ship lifts, they can help ships overcome altitude differences which would normally be impossible, e.g. at waterfalls; the creation of a reservoir creates significant backwater, which increases water depth further upstream, allowing ships with higher tonnage to pass those parts of the river, as well as generally reducing rapids and other instabilities in the river's water flow pattern (United Nations Economic and Social Commission for Asia and the Pacific, 2003: 124-126).

While several large scale dams are situated at the Yangtze, the scale of Three Gorges Dam outweighs even the other dam's combined impacts. The reservoir area of the TGD is 39,300 km³, which exceeds even the combined values of the next largest reservoirs (namely, Ertan 二滩水库, with 5800km³ or Shuibuya 水布垭水库 with 4580 km³; Food and Agricultural Organization of the United Nations, 2013b). Because of the dominance of the TGD, and the fact that assessing the impacts of all dams at the Yangtze would exceed the scope of this paper, the analysis will focus instead on the Three Gorges Dam.

The backwater from the TGD's reservoir has had significant impact as far as 430 km upstream of the reservoir by raising the average water-depth to 70m. The downstream discharge at Yichang has been increased by more than 60%, from 3,000 m³/s to 5,000 m³/s during the dry season (Reynolds, 2011: 4). As a result, the majority of the Yangtze's rapids and shoals in this area have been submerged, the flow velocity was reduced and one-way control sections were removed (Reynolds, 2011: 4). All this led to a significant increase in navigation safety. In addition, the increased water depth allowed for the navigation of higher gross tonnage vessels through these parts of the river (United Nations Economic and Social Commission for Asia and the Pacific, 2003: 126).

In terms of shipping capacity, these effects have multiplied the annual one-way capacity five-fold, from 10 million tons to 50 million tons. Prior to the TGD, the IWT to Chongqing could only be covered by 3,000 tonnage vessels, due to the aforementioned risks and low water depth (Ponseti and López-Pujol, 2006: 167). Since the reservoir impoundment, 10,000 ton ships are capable to navigate the Yangtze up to Chongqing for half the year (during the flood season), while 5,000 ton ships are able to reach Chongqing at any time. In addition to the increase in total transport volume, the usage of large vessels also decreased the average transportation costs by approximately 37% (Reynolds, 2011: 4).

The navigability of 5,000 and 10,000 tonnage ships up to Chongqing was not made possible by the positive effects of the TGD reservoir's backwater alone. To enable ships of such scale to cross the height difference at Sandouping (三斗坪镇), a large scale ship lift system was a necessary part of the TGD. It allows ships of up to 10,000 tons to bridge the vertical gap of 113 meters between the upper and lower water levels (United Nations Economic and Social Commission for Asia and the Pacific, 2003: 126). With a total length of 1.6 km, the ship lift consists of two separate facilities: the first one is a double-way five stop ship lock with 10 chambers, each of 280x34x5 m, which allows for the transport of most ships with a tonnage of up to 10,000 tons (Ponseti and López-Pujol, 2006: 168). In addition, the system also has a vertical ship lift of 120x18x3m which is used mainly for smaller vessels of up to 3,000 tons as well as passenger ships (Ponseti and López-Pujol, 2006: 168).

The TGD's ship lift system has transported more than 190,000 vessels between the completion of the first ship lock module in 2003 and the end of 2005, carrying more than 5.2 million passengers and 89 million tons of freight (Ponseti and López-Pujol, 2006: 168).
The Chinese effort to make the Yangtze navigable by larger vessels through the Three Gorges Project has yielded significant positive results. The transport volume increased by the factor three, from 850,000 container units in 2000 up to 2.6 million container units in 2010 (United Nations Economic and Social Commission for Asia and the Pacific, 2003: 126).

The situation in **Japan** is completely different. While several Japanese publications discuss the major importance of IWT for the island nation, this exclusively refers to the rather uncommon approach of Inland Water Transport as a term for coastal transport (Ministry of Land, Infrastructure and Transport, 2006: 4-9).

Actual “Inland” Water Transport however, is virtually not existent in Japan, due to its geographical structure. Japans main islands have an average breadth of 180 km, and are separated in the center by mountains, which thereby create a water parting. As a result, most of Japans rivers tend to be very short: The Shinano River (信濃川), Tone River (利根川) and Ishikari River (石狩川) are the country’s longest rivers with a length of only 367 km, 322 km and 268 km respectively. In addition to this, Japanese rivers tend to be broad, but very shallow and steep (Ministry of Land, Infrastructure, Transport and Tourism, 2007; Food and Agricultural Organization of the United Nations, 2013a). A third factor is the distinctive difference between seasons in Japan: Rivers’ water levels are very volatile depending on the weather situation, typically causing floods during spring and late Summer, as well as desiccation of rivers during dry periods. These changes can happen in short frequencies, making river navigation even less viable due to the lack of predictability (Ministry of Land, Infrastructure, Transport and Tourism, 2007).

While Japan has numerous rivers, for the aforementioned reasons, not a single one of them is considered to be navigable by transport or passenger ships. The degree to which Japanese rivers are unfit for shipping is not an effect of modern large scale ships either. Historical documents dating back to the Edo period (17-19th century) already note that transport and shipping is only relevant along the coastal areas (Ministry of Land, Infrastructure and Transport, 2006: 4-6).

Average cargo volume has increased in the order of magnitude for various types of transportation in Japan over the last 50 years, for instance coastal transport from 25,000 million ton/km up to 240,000 million ton/km or road based transport from 5,000 million ton/km to 300,000 million ton/km. Despite the obvious need to establish a better transport infrastructure, river based IWT is not even mentioned in official statistics of the Japanese Ministry for Land, Infrastructure and Transport (ASEAN-Japan Transport Partnership Information Center, 2012).

It may be a special form of “chicken and egg”-problem to figure out whether Japanese dams were not built to improve river navigability because there was none to begin with and it was therefore not deemed necessary, or whether the geographical situation is so restrictive that even hydropower dams were not able to improve the situation enough to make river-based IWT viable in Japan.

Conclusion

IWT in **China** is of significant economic importance; it is responsible for a large amount of the country's total internal transport volume and is the only cost efficient way to supply certain parts of the country, including its largest city, Chongqing. Hydropower stations contribute significantly to making IWT even more viable, by reducing risks, decreasing costs and opening up rivers for larger vessels. This positive effect has also been realized by the government and is supported significantly through the allocation of funds from various infrastructure projects towards hydropower development in combination with IWT supporting features such as ship lift systems. The Chinese IWT sector benefits significantly from hydropower; and the government has taken steps to further utilize these positive effects, making hydropower in this regard very sustainable and resulting in a rating of +1.

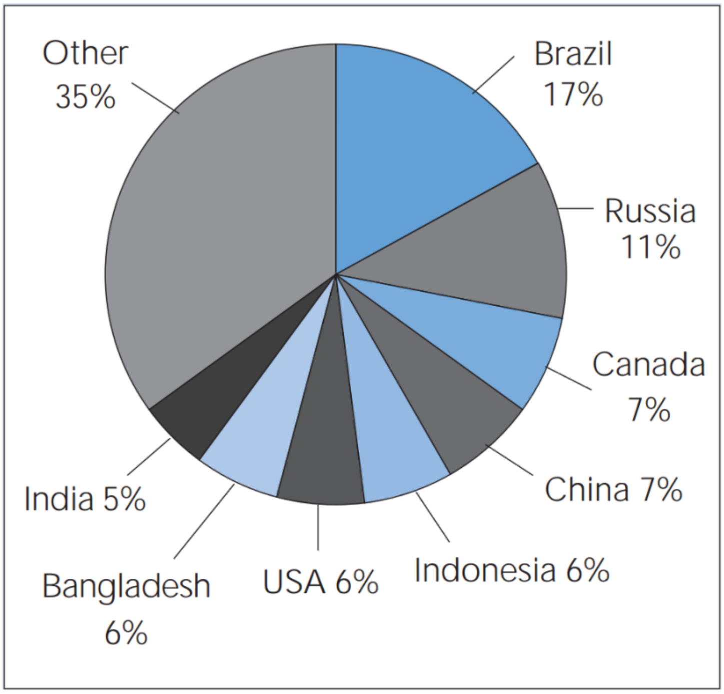
Japan, on the other hand, has no river-based Inland Water Transport at all. This is due to the country's geological features. While the Japanese dams tend to be of smaller size than the Chinese ones and Japan has nothing that comes close to the impact exerted by the TGD,[10] this situation is not a negative impact of dam construction in Japan. If hydropower stations have any impact on river based IWT in Japan, it is that the geographical foundation and the resulting IWT situation is further carburized due to the lack of ship lift systems. Because this does not constitute a negative impact on the economy, the rating for Japan is 0.

4.1.3 Irrigation

Irrigation is an important part of the positive effects provided by hydropower stations. Even more so in countries like China and Japan, which have to deal with an over-proportionally high population compared to the limited amount of arable land and fresh water. The additional agricultural production capacity through advanced irrigation mechanisms and additional water supply provided by hydropower stations does not only provide economic benefits, but also contributes indirectly to a wide variety of area, e.g. by reducing the cost for agricultural products which in turn positively affects various other areas such as social security and public health.

[10] It has to be noted that the positive backwater effect of the TGD reservoir extends 430 km upstream, which is 60 km more than the longest Japanese river.

Regarding the total amount of available fresh water resources, the **Chinese** supply can be considered sufficient for the total population size. However, when factoring in the distribution of these fresh water resources, serious issues become apparent. While South China has water resources in abundance, the country's north is plagued by droughts and general water scarcity, affecting more than 400 million people and 600 cities on a frequent basis (Ponseti and López-Pujol, 2006: 169-170).



The situation is especially problematic in the north-western area of the country, where precipitation can be as low as 300 mm per year (Zhang, 1999: 6).

Figure 4.4: World's Distribution of Fresh Water (World Commission on Dams, 2000: 7)

Agricultural use is one of the biggest sources of water consumption in China, accounting for 50% - 60% of the national water supply in 2000. Irrigation is a core requirement to keep the Chinese agricultural industry functional: more than 40% of the utilized land is only arable with sufficient irrigation, which translates to approximately one third of the total Chinese food production that is only possible due to irrigation (Zhang, 1999: 6).

According to Zhang Lubiao (张陆彪) from the Chinese Academy of Agricultural Sciences (CAAS, 中国农业科学院), this is expected to further advance: By 2025, the share of food generated by irrigated land will be approximately 80%. As such, hydropower stations play a key role in providing the required water resources for this increase in irrigation (Zhang, 1999: 5-6).

In addition to irrigation, the lack of sufficient water supply also causes significant economic damage each year. It is estimated that up to 17% of the Chinese harvest is lost due to water shortages on an annual basis. Industrial losses (e.g. due to blackouts of water-based cooling systems) are not as significant, but are nonetheless occurring, estimated at roughly 20 million Euro annually (Ponseti and López-Pujol, 2006: 170). Without sufficient counter-measures, this issue is expected to worsen, as water consumption still increases on a yearly basis (Ponseti and López-Pujol, 2006: 170).

While hydropower stations can contribute significantly to providing additional water to areas with insufficient supply, it is difficult to assess to what degree water supply can be provided, because of the large amount of factors influencing the availability of irrigation support, as displayed by figure 4.5.

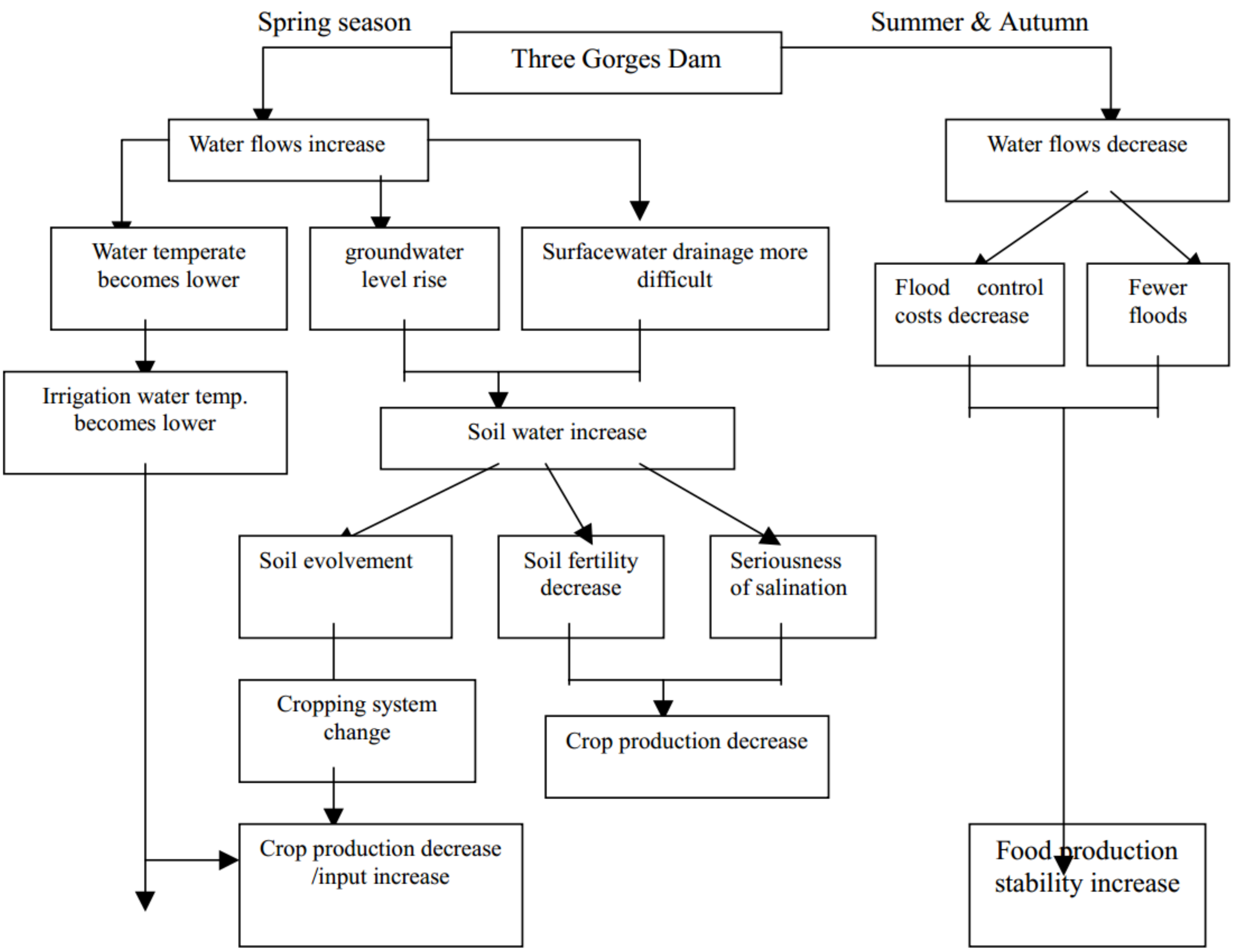


Figure 4.5: Impacts of the TGD on Downstream Agricultural Development (Zhang, 1999: 10).

South to North Water Diversion

The South to North Water Diversion (南水北调工程, also commonly referred to as South-North Water Transfer Project, SNWTP) is arguably the largest single infrastructure project China has ever undertaken, with an estimated cost of 62 billion USD (three times as much as the TGD). Its purpose is to divert water from major rivers and reservoirs in southern China to the north in order to better distribute and utilize China's water resources. If completed according the current plans, it will be able to transfer up to 45 billion m^3 water per year. (Office of the South-to-North Water Diversion Project Commission of the State Council, 2013) With 1426 m^3/s, this quantity would place the SNWTP as the world's 61th largest river according to water discharge capacity. Unlike normal rivers, however, the SNWTP water would be completely controlled by human will and therefore provide a much higher utilization rate in terms of irrigation and water supply). After the second phase of construction, the transferred amount of water is planned to amount to 70 billion m^3/year (Ponseti and López-Pujol, 2006: 170).

With the current water deficit of northern China, estimated at 40 billion m^3/year, the SNWTP would completely resolve this issue, providing significant economic benefits, mostly from additional agricultural production, but also from industry and a variety of other aspects.

In order to gather and control the water masses required for the SNWTP, a large amount of infrastructure is necessary, which relies primarily on hydropower stations (Ponseti and López-Pujol, 2006: 169). The SNWTP is split up between three routes, the eastern, central and western one. Using diverted water from the Yangtze, the eastern route will supply the provinces Shandong (山东省), Jiangsu (江苏省) and Anhui (安徽省), as well as the Tianjin municipality (天津市). The central route will divert water from the Three Gorges Dam (Hubei province 湖北省), the Danjiangkou reservoir (丹江口水庫, Henan province 河南省) as well as several smaller reservoirs in the Hebei province (河北省) to Beijing (北京市). The western route has not yet reached construction phase, but is supposed to transfer water from several Yangtze tributaries, namely the Tongtian (通天河), Yalong (雅砻江) and Dadu Rivers (大渡河) to the Yellow River (黄河) (Ponseti and López-Pujol, 2006: 170).

In addition to the indirect irrigation benefits of dams provided by enabling the SNWTP, hydropower stations can also provide direct irrigation and water supply for agricultural areas in their direct proximity.

The Three Gorges Dam is a prime example of such benefits. The dam regularly discharges its stored water during the dry season between December and March. During the 2011 drought, the central Chinese provinces of Anhui, Hubei, Hunan (湖南省), Jiangsu and Jiangxi (江西省) experienced the worst drought in 60 years. By raising the water discharge flow from the standard 10,000 m^3/s to 12,000 m^3/s,[11] the TGD provided an additional 6 billion m^3 of water from its reservoir over the period of roughly one and a half months to downstream areas, enabling them to continue the irrigation of 575,333 ha of farmland (Xinhua, 2011).

In 2000, China's large dams alone were estimated by the WCD to provide more than 450 km^3 water storage. The completion of several large scale dams such as the Three Gorges (2008, 39.3 km^3 storage), Longtan (龙滩大坝, 2009, 29.3 km^3 storage), Xiaowan (小湾坝, 2010, 15 km^3 storage), Xiluodu (溪洛渡大坝, 2013, 12.6 km^3 storage), has extended this capacity significantly (Food and Agriculture Organization of the United Nations, 2013b).
More recent data from the United Nation's Food and Agricultural Organization (FAO) amount the current combined reservoir capacity for China's 722 largest dams at 492 km^3 (492 billion m^3; Food and Agriculture Organization of the United Nations, 2013). According to WDC data, 17.6% of China's total arable land is irrigated with water provided by hydropower stations' reservoirs. This share is slightly higher than the 14.5% average of Asian countries which are significantly engaged in hydropower development (see table 4.7). In regards to these data it has to be noted that the information is rather outdated, gathered during the late 1990s. As has been shown, China has added many large scale multipurpose hydropower stations since then. Additionally, the completion of the SNWTP will also significantly increase this share, as irrigation supply for northern China is one of its main purposes. Unfortunately, the WDC data are the latest set of comprehensive data available for irrigation.

[11] Put into comparison, 2000m^3/s of additional water discharge amount to the total water discharge of the Rhine.

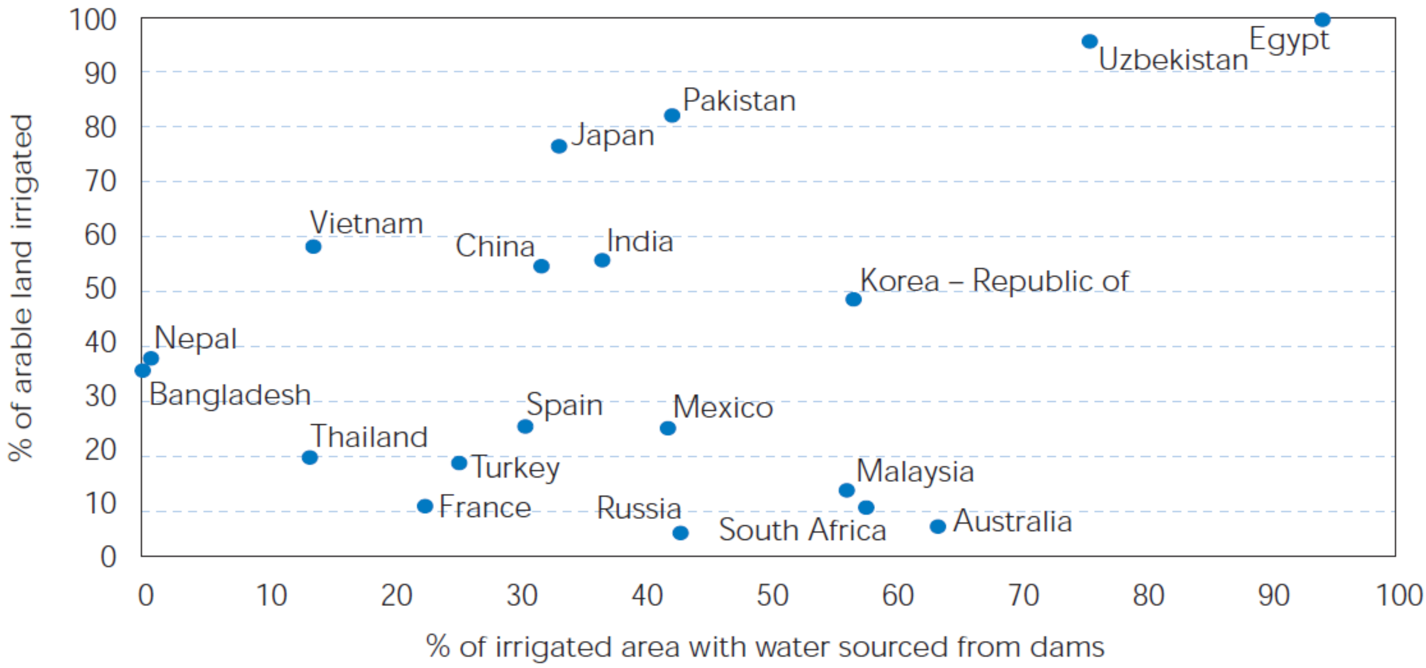


Figure 4.6: Hydropower Share of Land Irrigation (World Commission on Dams, 2000: 13)

Country	Reservoir Capacity (in billion m³)	% of arable land irrigated	% of irrigated area sourced from dams	% of arable land irrigated by dams
Bangladesh	22	36%	0%	0%
PR China	**492.5**	**55%**	**32%**	**17.6%**
India	259.4	56%	36%	20.2%
Japan	**19.6**	**77%**	**34%**	**26.2%**
Korea, Republic of	15.7	49%	56%	27.4%
Malaysia	22.5	14%	56%	7.8%
Nepal	0.09	39%	1%	0.4%
Pakistan	27.8	82%	42%	34.4%
Thailand	49.9	20%	13%	2.6%
Vietnam	44.4	58%	13%	7.5%
Average	**95,4**	**48.6%**	**28.3%**	**14.5%**

Table 4.7: Comparison of Irrigation Percentages for Selected Asian Hydropower Nations (World Commission on Dams, 2000: 13; Food and Agricultural Organization of the United Nations, 2013b; author's calculations)

Japan has a long tradition of utilizing dams for irrigation purposes, going back to ancient earthen dams for the water supply of paddy fields, some of which are still in operation today (Food and Agriculture Organization of the United Nations, 1997). With the beginning of industrial and modern hydropower development in Japan during the 1920s and 1930s, irrigation support was the most important secondary function of hydropower stations (Food and Agriculture Organization of the United Nations, 1997).

After World War II, large scale multi-purpose dams became the standard type of hydropower station developed in Japan. In 2013, Japan had roughly 542 major dams (above 15m), with a combined reservoir capacity of 19,557 billion m^3. Counting the dams currently under construction, the total storage capacity will increase to approximately 29 billion m^3 (Food and Agriculture Organization of the United Nations, 1997).

One characteristic of Japanese hydropower is to combine as many positive benefits during dam development as possible, leading to the high share of multipurpose dams in Japan (Yamaguchi, Kobori and Sakamoto, 2006: 1-2). As a result, the Japanese share of land irrigated by hydropower water supply is significantly higher – at 26.2% - than the Asian average of 14.5% (Food and Agriculture Organization of the United Nations, 1997).

Conclusion

Despite massively different geological characteristics, both China and Japan surpass the Asian average values in terms of their hydropower stations' relevance for their respective agricultural sectors.

In **China's** case, 17.6% of land is irrigated by hydropower stations, which accounts for more than 50% of the total water available for irrigation. This slightly exceeds the Asian average of 14.5%. However, these numbers are misleading, because they rely partially on the final report of the WCD, which was published in 2000, and utilized data gathered during the late 1990s. The United Nation's Food and Agriculture Organization's databases provide a wide variety of irrigation-related information, but lack some important data necessary to relate and interpret the raw numbers.

However, it has been shown that the PR China's hydropower capacity underwent a massive expansion since 2000, with a total increase of over 100 km^3 total reservoir capacity (Food and Agricultural Organization of the United Nations, 2013b).

Additionally, the SNWTP will significantly increase the share of water used for irrigation, although as of yet it is unclear by how much. On this background, hydropower in China is very sustainable regarding water supply, resulting in a rating of +1.

While **Japan** did not add as much reservoir capacity over the last 15 years, it already exceeded the Asian average by far, with 26.2% over 14.5% of arable land irrigated by hydropower plants, thereby also achieving a rating of +1.

4.2 Ecological Indicators

4.2.1 Greenhouse Gas Emissions

The assessment of hydropower related Greenhouse Gas (GHG) emissions comprises two parts. Firstly, the general, and non-country specific, GHG emissions caused by the construction and ("traditional" assessments of) operation of a hydropower station: They relate to the construction of the dam, including the construction of the dam wall, electromechanical equipment, related infrastructure and service projects, as well as all transport and service activities, such as clearing of the impoundment area. They also include the "traditional" view of emissions produced by operation and maintenance activities (Steinhurst, Knight and Schultz, 2012: 11-13).

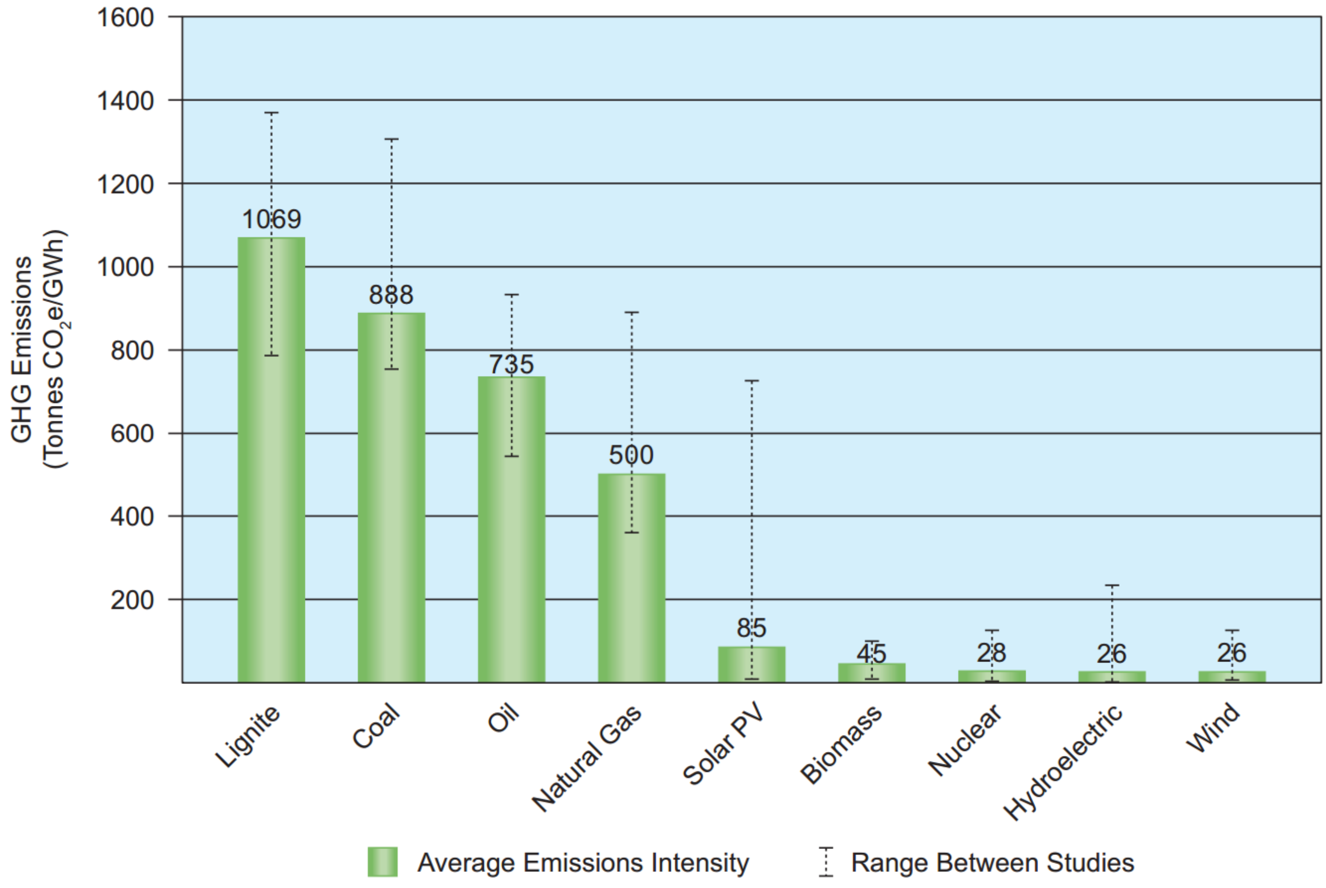
The average emissions related to the construction over the course of a hydropower plant's average lifetime amount to 9.3 g CO_2eq/kWh,[12] out of which almost 40% are associated with the penstock. Over the course of its lifetime, operation and maintenance amount to only 17.2% of the GHG emissions, while the remaining 82.8% are associated with the enormous upfront construction investment (Hondo, 2005: 2051).

Item	Emissions (g CO_2/KWh)	Share (%)
Machinery	0.9	8.0
Dam	0.5	4.5
Penstock	4.5	39.8
Other Foundations	2.4	21.0
Site Construction	1.1	9.6
Total Construction	9.3	82.8
Operation	1.9	17.2
Total	**11.3**	**100**

Table 4.8: Life Cycle GHG Emissions for Hydropower (based on Hondo, 2005: 2051)

[12] CO_2eq (Carbon dioxide equivalent) is a way to measure the impact of Greenhouse Gases such as Methane (CH_4), Nitrous Oxide (N_2O), etc. in a unified way by converting the total environmental impact of all GHG into the equivalent amount of CO_2.

Compared to other energy generation sources, hydropower performs very well with an average of 26g CO_2eq/kwh. Traditional energy sources such as coal, oil or natural gas reach much higher emission values with 888, 735 and 500 g CO_2eq/kwh respectively. Among renewable energies, hydropower is on par with wind (26g CO_2eq/kWh), and outperforms biomass (45g CO_2eq/kWh) and photovoltaic solar energy (85g CO_2eq/kWh) by a significant margin (World Nuclear Association, 2011: 7).



Graph 4.9: GHG Emissions by Energy Type (World Nuclear Association, 2011: 7)

Traditional Emission Assessment

Hydropower does not generate energy through combustion of carbon based fuels. Therefore, this technology does not emit GHG in the traditional sense and a definite amount of emissions are mitigated when producing energy with hydropower instead of combustion based power plants. There has been a lot of research to evaluate how much emissions are exactly mitigated per unit of energy under the assumption that hydroelectric power generation works emission-free. One of these approaches to quantify hydropower GHG emission mitigation is based on the Oak Ridge Competitive Electricity Dispatch (ORCED). It first asks the question "*If a kilowatt-hour were not generated at the hydro plant, what plant would have generated it?*" (Sale and Hadley, 2008: 2). It then utilizes the respective carbon intensity factor (see table 4.10) for carbon intensity factors of various common energy generation technologies) and the amount of electricity generated to calculate the amount of carbon that *would* have been emitted and is therefore mitigated by hydropower.

Energy Source	***Efficiency***	***Heat rate (Btu/kWh)***	***Carbon intensity factors***	
			(kg C/MBtu)	***(kg C/MWh)***
Coal Steam	33%	10,339	25.74	266
Oil Steam	33%	10,339	21.49	222
Gas Steam	33%	10,339	14.47	150
Oil -- Combustion Turbine	25%	13,648	21.49	293
Gas -- Combustion Turbine	25%	13,648	14.47	197
Gas -- Combustion Turbine	40%	8,530	14.47	123
Gas -- Combined Cycle	50%	6,824	14.47	99
Advanced Gas -- Combined Cycle	55%	6204	14.47	90
Coal Gasifier / Combined Cycle	50%	6,824	25.74	176

Table 4.10: Carbon Intensity Factors of Selected Energy Sources (Sale and Hadley, 2008: 4)

If a coal steam plant of 1000 MW/h generation capacity it would be replaced by hydropower for instance, a total of 266,000 kg carbon and 72618 kg CO_2eq would be mitigated per megawatt hour.[13] On this foundation and with information about the composition of China's and Japan's national energy production, it is possible to calculate the approximate amount of GHG emissions mitigated due to hydropower.

[13] With a molecular weight of 16gl for oxygen atoms (O) and 12g for carbon atoms (C), 1 kg CO_2 contains approximately 273g.

Reservoir Related Emissions

However, such an assessment of the hydropower related GHG emissions is incomplete and stems most likely from oversimplification. It follows the assumption that a man-made reservoir will not emit more GHG than a similarly sized natural water body (e.g. a river) and therefore does not require any analytical attention. This premise is incorrect in two regards. Firstly, even if the reservoir is just an extension of an already existing water body, such as a river, there are significant differences. Research has proven that GHG emissions in a standing water body are significantly higher than in a running river, due the various processes associated with the water's current and flow. Also, even if the reservoir is developed out of an existing lake, the surface area will be much greater than it has been previously by nature, thereby creating emissions that were not present before. Secondly, due to the impoundment and the resulting submersion of plants and animals, the biomass in reservoirs is usually of higher magnitude than it would be in a normal, naturally developed water body. As a result, the normal chemical processes in such an environment are significantly enhanced, leading to a substantial increase in emissions during the first 10 to 15 years after inundation, after which the emissions tend to decrease until they reach a level similar to that of natural water bodies (Barros et al, 2011: 594).

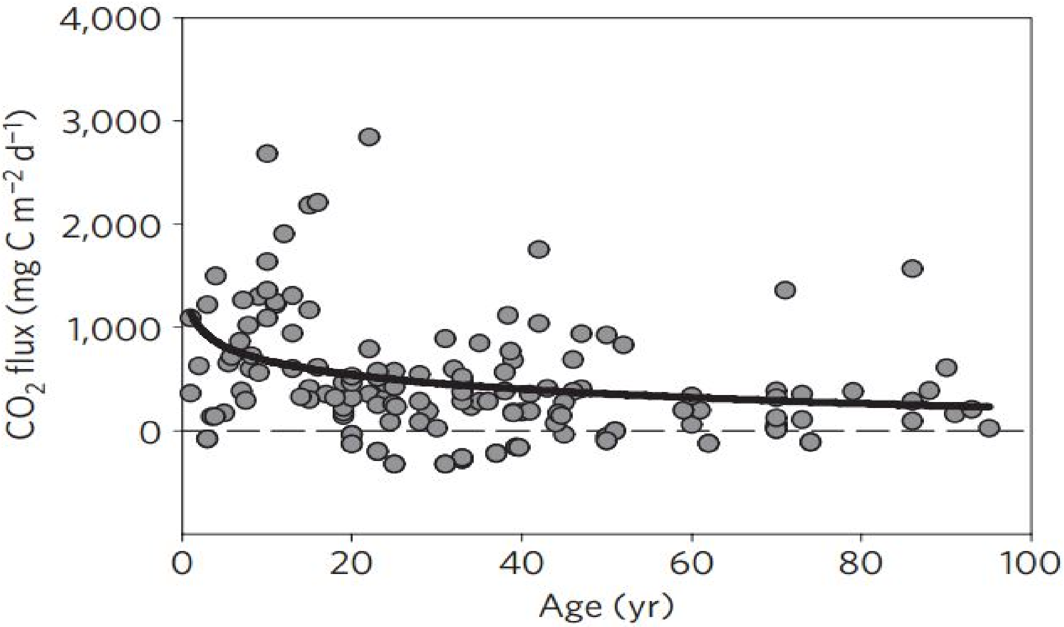
Research has shown that they are not only of significant volume, but they are also dependent on several factors that will vary between different countries and are therefore of importance for this assessment (Intergovernmental Panel on Climate Change: 471). The second part of this assessment is therefore to examine the emissions generated by reservoirs.

During the construction of a hydropower plant, the surrounding land or wetland is turned into a reservoir, which almost always includes the inundation of plants, which in turn lead to the submersion of organic carbon. The resulting emissions mainly contain carbon dioxide (CO_2), methane (CH_4) as well as nitrous oxide (N_2O) (Hertwich, 2013: 3). As mentioned before, the first 10 to 15 years after impoundment feature very high GHG emissions. The reason for this is, firstly, that the reservoir transformation creates an anoxic bottom layer, which, combined with the increased surface area, emits more CO_2. In addition, the dam stops the river's natural transportation of organic matter, which results in sedimentation and decay of this matter (Hertwich, 2013: 6).

The exact increase in GHG emissions is dependent on a variety of factors, such as oxygen concentration, water temperature, organic matter concentration, light (referring to absence of turbidity), bio-mass in the drawdown zone, sediment load and stratification of the reservoir body. Additionally, there are several secondary factors, such as wind speed, reservoir shape, rainfall, current speed and many more, which can also influence the specific degree of GHG emissions (Working Group on Greenhouse Gas Status of Freshwater Reservoirs, 2008: 3).

The interconnection of all these factors creates a highly complex overall process that is very difficult to assess comprehensively, especially on a national level. It also has to be noted that research in this regard is still very young and that there is a distinctive lack of consensus in regards to methodology and equipment used to assess GHG emissions at reservoirs (Goldenfum, 2009: 17).

For all these reasons, it is not feasible to conduct a country-level comparison of the emission values of hydropower facilities in China and Japan, or any other country for that matter. Nevertheless, this does not mean that there is no way to compare the two countries or discuss tendencies based on recent research, such as by Barros, who has studied the relation of reservoir emissions with various other reservoir characteristics. The first causal relationship indicated by his research is between reservoir age and emissions. As explained earlier, emissions during the first ten to fifteen years after reservoir impoundment are significantly higher than in any natural water body (Barros et al., 2011: 593-596).



Graph 4.11: GHG Emissions in Relation to Reservoir Age (Barros et al, 2011: 594)

This fact is important for the comparison of China and Japan, as both countries feature a very different developmental period in regards to hydropower. In the **Japanese** case, most hydropower plants have been build prior or shortly after the 2nd world war. In the 1960s, the Japanese period of big hydropower construction ended. Consequently, most Japanese reservoirs are older than 40 years. The average age of the 542 largest and most important Japanese hydropower plants is 54 years, averagely being in operation since 1959 (Food and Agriculture Organization of the United Nations, 2013b).

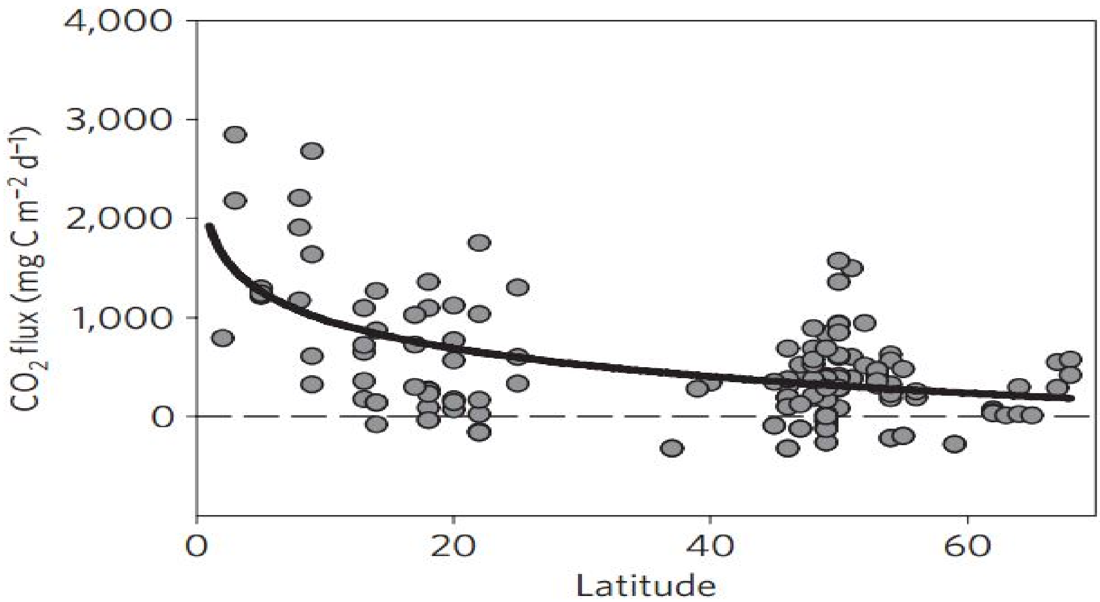
In **China**, the situation is different, as there was never a long-term "slowdown" regarding the construction of new hydropower plants. On the contrary, in recent times, the People's Republic of China has further accelerated the construction of new plants, both in number and size. Due to this, a significant amount of the total Chinese reservoir capacity is very “young” and currently in the high emission phase. As of 2014, the average age of the 620 largest and most important Chinese hydropower stations is 43 years, being built in 1970 on average (Food and Agricultural Organization of the United Nations, 2013b).

While this means that in both countries, the majority of hydropower reservoirs are older than 10 to 15 years, and the difference is not as significant, the graph also shows that, despite the leveling-out of GHG emissions shortly after the inundation, there is still a noteworthy difference between the emissions of a 43 year old reservoir and a 54 year old one. The situation becomes more obvious if the age per reservoir capacity is analyzed. In China, 101,275.5 million m^3 reservoir capacity has been created over the last 15 years. This equates 20.56% of China’s total reservoir capacity. In Japan, 1,179.4 million m^3 capacity has been added over the same period, which equates to only 6% respectively (Food and Agricultural Organization of the United Nations, 2013b).

This shows that the Chinese hydropower sector is not only in average younger but also that its share of high intensity GHG emission reservoirs is more than three times higher when compared to the Japanese hydropower sector.

Given the 12th Five-Year-Plan’s goal to develop even more hydropower plants, the existence of a large amount of high emission reservoirs in China will persist in the near future. As a consequence, the current state of hydropower in China is less sustainable in terms of GHG emissions.

The second factor is the relationship between latitude and emissions. Barros' team has also proven a direct relationship between the latitude of the reservoir and its emissions (Barros et al, 2011: 593-596). The closer a reservoir is to the equator, the higher tend its emissions to be.



Graph 4.12: GHG Emissions in Relation to Reservoir Latitude (Barros et al, 2011: 594)

The foundation for this relationship has been established by other scientists and, for instance, been supported by the IPCC's Renewable Energy Sources and Climate Change Mitigation Special Report, where significant differences between the emission of reservoirs located in different temperature zones have been shown.

GHG pathway	Boreal temperate		Tropical	
	CO_2 (mmol/m^2/d)	CH_4 (mmol/m^2/d)	CO_2 (mmol/m^2/d)	CH_4 (mmol/m^2/d)
Diffusive fluxes	-23 to 145 (107)	-0.3 to 8 (56)	-19 to 432 (15)	0.3 to 51 (14)
Bubbling	0	0 to 18 (4)	0	0 to 88 (12)
Degassing	-0.2 (2) to 0.1 (2)	n/a	4 to 23 (1)	4 to 30 (2)
River below the dam	n/a	n/a	500 to 2500 (3)	2 to 350 (3)

Table 4.13: Reservoir Emissions by Climate Zone (based on: Intergovernmental Panel on Climate Change: 473)

Further support for Barros' study is provided by the World Commission on Dams, which comes to similar results for a variety of case studies (World Commission on Dams, 2000: 76).

On this background, it has to be noted that two thirds of all Chinese hydropower plants are located in the south and southwest of the country, as well as further south than even the most southern Japanese hydropower plant (Zheng et al, 2010: 1392). While the difference is not very large in terms of latitude degrees, its existence should be taken into account, especially since large parts of China (30%) are considered to be tropical climate, Japan on the other hand has no hydropower stations located in tropical regions (Intergovernmental Panel on Climate Change, 2003: 3.282).

Conclusion

It has been shown that hydropower is, traditionally assessed, extremely sustainable and similar across countries in regards to GHG emissions. However, when including the emissions generated by reservoirs, the assessment's results change.

China is extremely likely to have significant higher reservoir emissions, due to its reservoirs being larger, younger, and located further south in average. Considering that China is the world's leading hydropower producer, with a total reservoir size larger than most other countries combined.

Japanese reservoirs, on the other hand, are in average significantly older and have a smaller reservoir capacity in relation to their generation capacity. Additionally, as a result of geographical characteristics, most Japanese hydropower stations were built in mountainous regions and are therefore far less likely to contain large amounts of biomass, compared to Chinese hydropower plants.

Despite the large amount of evidence indicating that significant amounts of GHG are emitted by Chinese and Japanese hydropower reservoirs (although it is likely that the Japanese emissions are significantly lower), the assessment lacks empirical data to evaluate and compare the actual amounts. The reason for this lies in the novelty of the knowledge of reservoir-based GHG emissions and the large amount of costs and planning required to gather the necessary data, particularly on a country scale.

However, not including the reservoir-induced emissions and evaluation this indicator on the basis of the traditional view of hydropower emissions would be methodologically and ethically wrong, considering that the analysis has shown that the reservoir-based emissions are of significant scale. The only remaining option is therefore to not include this indicator in the final evaluation at all.

4.2.2 Biodiversity

Biodiversity refers to a wide variety of effects that influence the flora and fauna in proximity to a hydropower plant, which also includes areas further downstream, if a direct causal relation is apparent, as well as effects exerted by related infrastructure and service operations.

First, it is important to assess what kind of impacts on biodiversity can be caused by hydropower. According to the International Centre for Environmental Management, there are six direct impacts (International Centre for Environmental Management, 2010: 17):

- Habitat loss

Causes for habitat loss include the flooding of the reservoir and the dam, as well as infrastructure construction works, which lead to loss of suitable living area for various animal species. As a consequence, not only species of the flooded area are affected, but also aquatic species further upstream due to substantial changes in flow patterns, temperature and other factors.

- Direct Loss of Species

An even more severe effect of hydropower stations is the direct loss of species, which comprises the loss of entire endemic species or populations. This loss mainly occurs as a result of wildlife drowning, but, in case of aquatic species, also due to the turbines of the hydropower station.

- Habitat Fragmentation

A major sub-category of habitat loss is habitat fragmentation. Caused by the construction of objects (e.g. infrastructure such as roads, fences etc.), it prevents terrestrial animals from accessing parts of their natural habitat. Birds and fish species can therefore only be affected by habitat fragmentation in rare cases (the prevention of migration, e.g. through dams, is not considered here, because, while preventing movement, the affected areas are usually not part of the species' living habitat but rather a travel route).

- Impediments to Species Migration

Another negative impact on biodiversity is impediment to species migration, caused by the dam blocking the migration of species, including riparian species. Typically, fish species are affected, in particular diadromous ones like salmon that migrate between fresh and salt waters in the course of their reproduction cycles.

- Genetic Isolation of Populations

Both habitat fragmentation and migration impediments can lead to long-term issues caused by genetic isolation of populations. While the issue has been promoted as an important problem by academic literature, specific information on the extent and long term effects are not yet available.

- Invasive Species Propagation

Finally, most prominently in aquatic habitats, the decreased ecosystem vulnerability, e.g. changes to water quality, availability of nutrients, etc., can lead to invasive species propagation, which in turn generates reduced water movement, oxygen saturation and light penetration. These factors particularly endanger endemic species (International Centre for Environmental Management, 2010: 17).

Furthermore, there are seven indirect impacts of hydropower stations, which are closely related to the direct impacts:

- Changes to a river's flow regime
- Changes to a river's flooding regime
- Changes to a river's sediment patterns
- Changes to natural shorelines in riparian ecosystems
- Water quality deterioration
- Increased pressure on natural resources
- Induced human development

  (International Centre for Environmental Management, 2010: 17-18)

When assessing these types of impacts, two different categories regarding the timeframe of their appearance and relevance can be distinguished. The first one comprises impacts caused by and during the construction of the dam and its related infrastructure. This also includes the initial reservoir impoundment. Unlike the second category, the impacts and their respective causes during this phase are non-recurring. For instance, the initial inundation often causes significant drowning of wildlife in the reservoir area. However, this effect only occurs once and over a short period of time.

While this stage certainly has a significant impact on biodiversity, it will not be assessed in this paper. The reason lies in the non-recurring nature of these impacts. The effects are only relevant during a certain part of the construction and cease to exist after completion of this part – a time frame which is insignificant in relation to the average lifetime of a hydropower facility. The impacts are not lasting, not sustained. Taking such events into account would deteriorate the assessments' results. This paper aims to assess the current sustainability of hydropower in China and Japan. This means that construction impacts of hydropower plants that have long been completed – which constitute the absolute majority – could not be included because it is impossible to obtain reliable data. Especially so, since it is unlikely that such data was even gathered during the time of construction. Biodiversity impacts just slowly attain awareness among experts and companies, it is highly unlikely that they were considered during hydropower construction in the past. Including data from stage one impacts would therefore rely only on plants which are currently in construction, which would in turn distort the results of the analysis, as the number of completed hydropower plants is substantially higher (Food and Agricultural Organization of the United Nations, 2013b).

The second phase comprises the actual operation of the hydropower plant. Since no more construction efforts are present during this stage, several direct impacts, such as habitat loss, fragmentation and subsequent direct loss of species (the exception being death of fish due to dam turbines), as well as genetic isolation of populations are not relevant in this stage. As a consequence, the relative share of impacts on terrestrial and avian species decreases significantly. Accordingly, impediments to species migration (which mainly affect fish species) constitute the majority of biodiversity impacts after the construction phase has ended. The impacts of stage two are mainly exerted onto aquatic species. Contrary to phase one, land and avian animals are subject to only minor impacts.

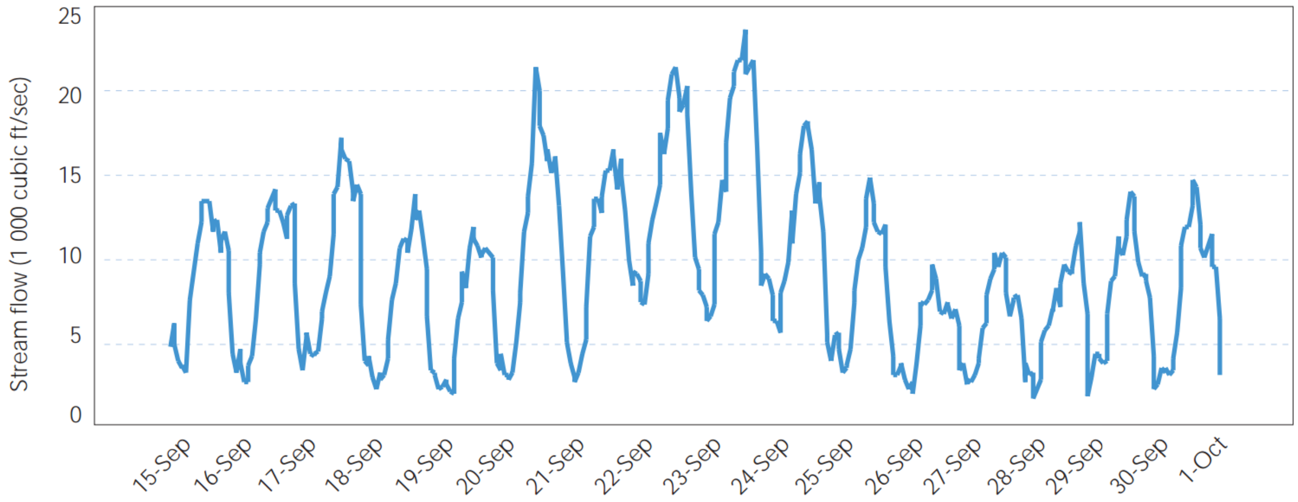
As terrestrial habitats are insignificantly affected during the second phase, the following analysis is concentrating on aquatic species.

Dams affect aquatic species in many different ways. At least four of the seven indirect impact types – Changes to river's flow regimes, flooding regimes, sediment patterns and water quality deterioration - are of primary relevance for aquatic species, while negligible for terrestrial species.

Furthermore, for fish populations, the impacts caused by a dam are not limited to the immediate physical proximity. They can influence populations even several hundred kilometers further up- or downstream, including populations whose main habitat is the ocean.

The reason for this is that dams inhibit fish to pass them, impeding the common migration process of species during certain times of their life cycle, for instance to reproduce. To deal with these issues, the so called "fish ladders" were developed. They are supposed to act as a bridge for the fish to cross the dam. Fish ladders have been held in high regard by dam operators and have been promoted as a tool that can solve the most negative biodiversity impact of hydropower facilities (Brown et al., 2013: 280-286). However, recent research indicates that fish ladders are highly ineffective. For instance, a study by Brown came to the result that only about 3% of the migrating fish population managed to pass the first fish ladder. Even less of those fish were able to pass the ladders at other dams further upstream, let alone to move through these a second time in order to return to their place of origin. (Brown et al., 2013: 280-286).

Additionally, several fish species were not able to use fish ladders at all due to construction issues (Brown et al., 2013: 280-286). A third problem of fish ladders is that they only address one issue that leads to fish being incapable of passing a dam. Not only the physical presence of dams is obstructing fish migration. Various subtle factors, such as changed flow patterns (e.g. still waters in the upstream area), velocity and water temperature impact the navigational abilities of fish species, which also often prevent fish from using the "ladders". Graph 4.14 shows the fluctuation of an average dam's daily stream flow regime. During the daily peak times of energy demand (typically between 02:00 pm and 07:00 pm) as much as 24,000 m^3/s water can be discharged, while the minimum (04:00 am) may go as low as 3,000 m^3/s. As a consequence, the river's flow pattern is massively disturbed. Additionally, the discharge through a dam's spillways can cause the water to become oversaturated with gas, which in turn has strong negative impacts on certain aquatic species, similar to the decompression sickness that divers can experience when they traverse too much vertical distance in too short of a timeframe. At least one fish species was proven to have been extinguished as a result of this effect (World Commission on Dams, 2000: 79-80).



Graph 4.14: Dam Stream Flow Fluctuation (World Commission on Dams, 2000: 79)

In addition to those issues, a study by Ziv et al. has proven that the cumulative impact of several hydropower dams exceeds those of a single dam with similar capacity and size (Ziv et al., 2011: 5611-5613). This is caused by the mutual amplification of negative impacts, e.g. the unnatural flow patterns in the backwater of one dam and the discharged spill water of another dam, resulting in even more “chaotic” water flow characteristics, which ultimately impacts fish more severely than the backwater or discharge water of a single, larger dam would have. This means, that not only the total size of dams along a river is relevant in regards to their impact on fish biodiversity, but also the absolute number (Ziv et al., 2011: 5611-5613).

Similarly to most other indicators analyzed in this paper, data gathering on biodiversity is rather difficult for several reasons. Firstly, biodiversity and sustainability in general, have not been influential concepts for a long time, especially when large scale companies were involved and even less so in countries where environmental movements were comparatively weak, as in China and Japan (see also chapter 4.3.2; Ho, 2001: 903-906; Toshiko, 1999: 100-104).

Therefore, biodiversity data in these countries simply did not exist until recently and is still not available in sufficient quantity. Studies, such as the one from Zhai and Cui, were the first of their kind in their countries and reliable data are still extremely limited (Zhai and Cui, 2007: 106-114). While awareness of this topic is slowly increasing, general acknowledgement as one of the core issues to address when planning and building hydropower plants is still lacking. The immense investment necessary to acquire the necessary long-term data further hinders such a development (Kibler and Tullos, 2013: 25-27).

In addition to data issues, there is also the problem of intended limitations. In the case of China, for instance, a significant amount of data is not available because it is withheld in accordance to the Chinese State Secrets Act (中华人民共和国保守国家秘密法). This is particularly common in cases which are nationally and/or internationally controversial, as in the Nu River development (Kibler and Tullos, 2013: 7).

While it may be viable to conduct a study on the exact impacts and consequences of a single hydropower project, such a study would have to begin even prior to construction with a snapshot assessment of the initial situation of wildlife and flora, and would then have to continue with monitoring of the construction and at least a couple of years of normal operation. In addition to that, it would be necessary to include areas further downstream into the monitoring. If not earlier, then - at the latest - at this point, differentiating between impacts of the hydropower plant and of the multitude of other human activities on flora and fauna would become extremely difficult. Moreover, such studies would require a major investment, even if conducted for a single project. Hence, nationwide data gathering of such a scale cannot be expected for the foreseeable future.

For these reasons, it is not possible to directly and comprehensively assess the impact of hydropower on the respective ecosystems. Instead, an indirect approach has to be applied. Firstly, it will be assessed how severe the impact of hydropower on biodiversity in China and Japan can potentially be. While the loss of life is deplorable in any case, there is a significant difference in relevance between the loss of wildlife which is endemic and those which is not. The loss of endemic species has an enduring negative impact on the earth’s overall biodiversity, and therefore has to be considered as much more impactful.

As mentioned before, the measurable impact of hydropower primarily affects fish species, for which a comprehensive assessment is more viable due to the fact that hydropower stations are able to affect fish population far beyond their immediate proximity due to influence on various factors such as flow regimes, shoreline alterations, etc.

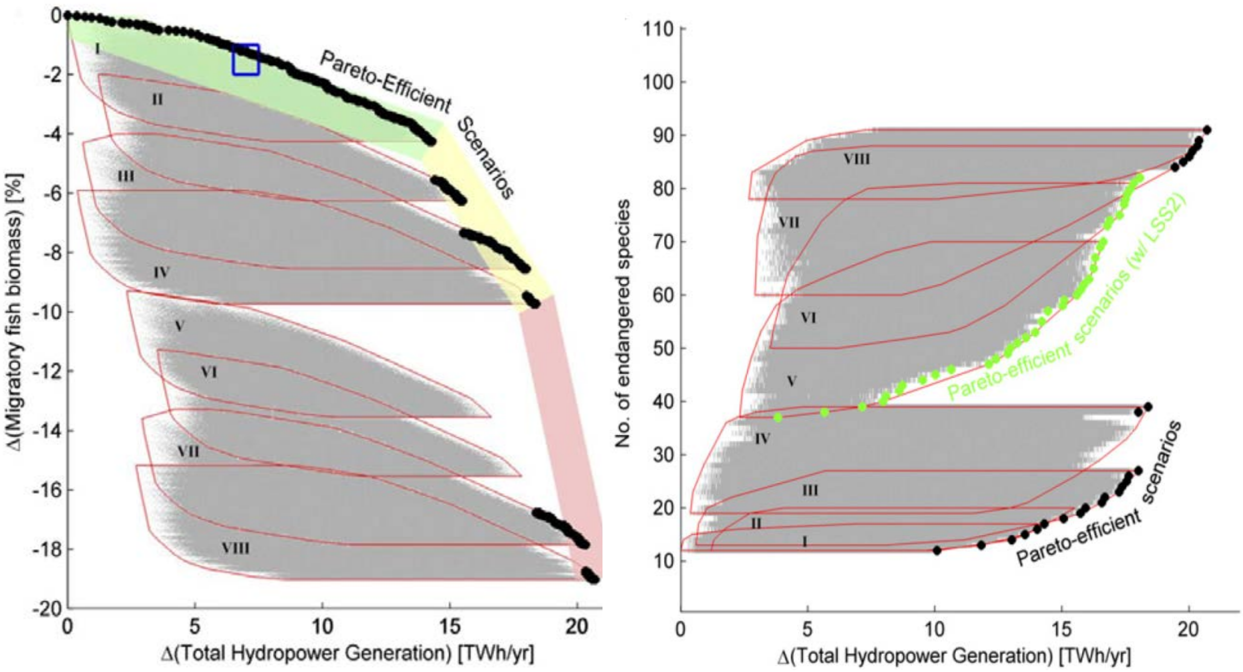
In addition, anadromous and catadromous fish species are affected by migration impacts no matter where their actual habitats are. For these reasons, fish species that are either fresh water fish or anadromus or catadromous can be considered as generally affected by hydropower.

Secondly, assessing relevant cases in China and Japan, while not necessarily representative, can provide a context for the relation of hydropower and endemic species in both countries.

China has a large amount of endemic wildlife, including approximately 73 mammal species, 99 bird species, 26 reptile species, 30 amphibian species and 440 fish species. Among these, the share of endemic fish and mammal species is particularly high within their respective classes, amounting to 15.7% and 14.6% (Biodiversity Committee of the Chinese Academy of Sciences, 1992).

Ziv et al. have shown in their Mekong study (2011), that total hydropower generation has a direct causal relationship with decreases in overall fish biomass as well as an increased number of endangered species, as shown by the following graphs.

Graph 4.5 shows the change in migratory fish biomass in relation to increasing total hydropower generation. Areas I – VIII indicate different sections of the Mekong River Basin. The main result of the assessment was that fish biomass decreases in a non-linear way as more hydropower generation capacity is added: For each additional TW/h energy generation, up until 14 TW/h, fish biomass decreases at 0.3% per TW/h per year. Between 14 TW/h and 17.6 TW/h, the biomass decrease amounts to 1.3%, and beyond 17.6 TW/h fish biomass decreases at a rate of 4% annually per TW/h of additional generation capacity. Graph 4.6 shows a similar relation between endemic fish species and hydropower generation (Ziv et al., 2012: 5609-5611).



Graph 4.15 & 4.16: Fish Biomass and Number of endangered species in relation to total hydropower generation (Ziv et al 2011: 5612).

Considering the large number of endemic fresh water fish species in China, as well as the fact that the country is the world's largest hydropower producer, the impact of hydropower plants on fish biodiversity is naturally very strong. This effect is exemplified by the case of the Yangtze River Dolphin (Baiji, 白鱀豚). While it had been an endangered and endemic species with approximately 200 specimens before, the number further decreased as a consequence of the construction of the TGD, which ultimately led to the functional distinction of the Baiji Dolphin (Trade Environments Database Project, 1997). This case represents the first extinction of cetacean species in 20 million years and is directly attributable to the dam construction on the Yangtze (International Centre for Environmental Management, 2010: 19).

Another case study conducted by Chinese researchers in the Lancang River (澜沧江) region, as well as the Yuan River (沅江) region in southern China showed that the construction of multiple dams has almost tripled the ecological vulnerability in that area, leading to the death of a significant amount of wildlife (Zhai et al., 2007: 112-113).

The number of endemic species in **Japan** is significantly lower than in China, although less significant if put in relation to geographic size of the countries: 51 mammal species, 32 reptile species, 52 amphibian species as well as 297 fish species out of which 56 are freshwater, and 241 are marine species (Living National Treasures, 2014).

However, in regards to hydropower impacts, the relevant numbers are significantly lower: While Japan has a rather large amount of endemic fish, only about one fifth of those are fresh water specimen and therefore affected by hydropower plants. This makes hydropower in Japan less impactful than in China, in both total and relative terms (International Energy Agency, 2006a-g). Unfortunately, there are no reliable additional data available for the Japanese hydropower sector's impact on biodiversity.

Conclusion

While there are no empirical data available that specifically address the impact of hydropower on biodiversity on a regional scale for either China or Japan, this chapter showed that it is still possible to determine significant differences between both countries.

Firstly, China has a larger hydropower sector: It has more plants, a larger generating capacity, larger reservoir volume and longer backwater. The chapter has also shown that fish species are affected in various ways (e.g. due to changes in a river's flow pattern), that are not bound to the physical location of the dam. It can therefore be argued that fish are affected by hydropower, irrespective of where their natural habitat is located. Combined with the significantly higher number of fish species in general, as well as endemic species, the hydropower impact on biodiversity in China is more intense than in Japan.

However, the evaluation framework of this paper does not account for varying degrees of negative performance, and the impact of hydropower is neither positive nor neutral in China or Japan, resulting in a rating of -1 for both countries.

4.2.3 Sedimentation

Sedimentation of dam reservoirs is an ever increasing problem for hydropower stations. Dams significantly influence sediment transportation in rivers. They reduce a river's velocity and slope, which leads to decreased sediment carrying capacity. As a result, the natural sediment load is usually trapped within the storage basin and cannot be transported further downstream. This typically results in reduced energy generation and water storage capacity, as well as potential safety problems such as increased flood risk. Another negative effect of increased sedimentation is the substantial rise in maintenance and repair costs, as the wear and tear of the machinery becomes more intense (Xu, 2002: 154-163).

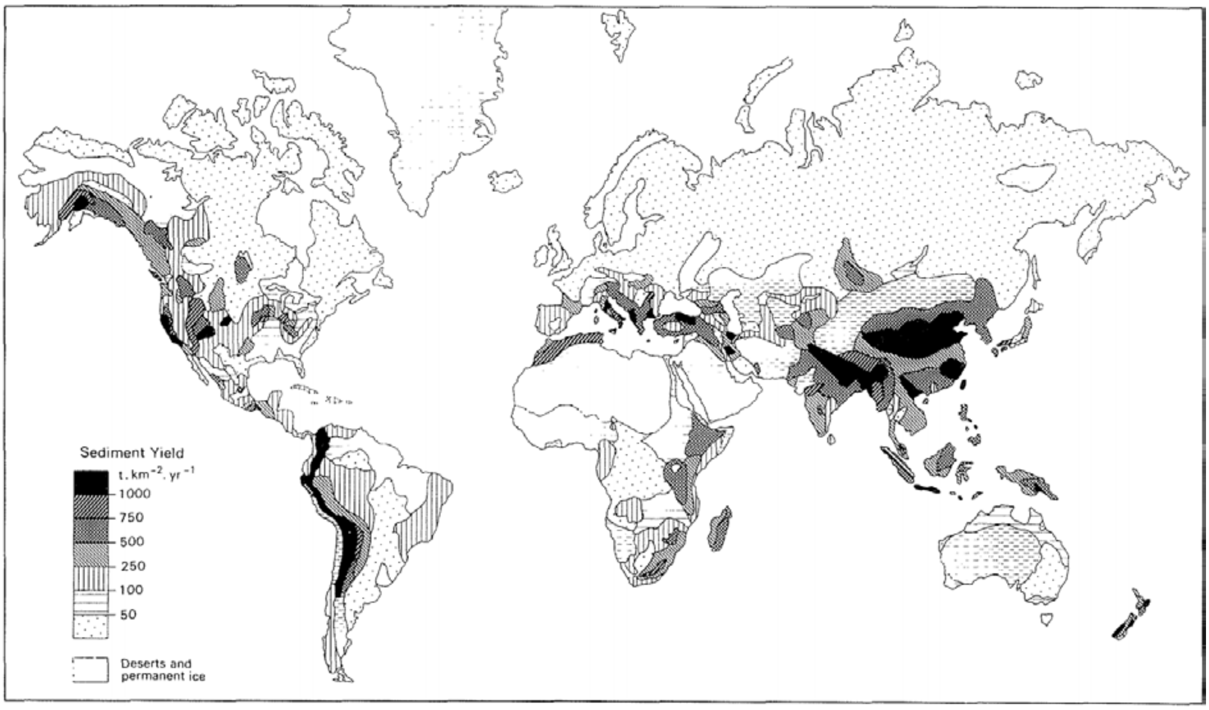
Data by Basson shows how severely sedimentation impacts hydropower, and how the accumulation of sediments in hydropower reservoirs will continue to become a more serious problem in the future: By 2006, 35% of the total storage capacity for hydropower reservoirs worldwide had been filled with sediment. By 2050, this value is expected to increase to approximately 70%. For Asia, the situation is even worse: by 2035, 80% of hydropower reservoirs are expected to be filled to a degree which significantly impacts performance and functionality (Basson, 2010). These expectations are based on statistics that show an annual loss of 0.85% total reservoir capacity in Asia. Comparatively speaking, Europe and Russia perform best in this regard, with 0.73%, while the Middle East faces the most significant problems with a sedimentation rate of 1.02% (Basson, 2008).

Region	Average Sedimentation Rate
Africa	0.85
Asia	**0.85**
Australia & Oceania	0.94
Central America	0.74
Europe & Russia	0.73
Middle East	1.02
North America	0.68
South America	0.75
Average	**0.82**

Table 4.17: Sedimentation Rates by Region (based on Basson, 2008)

In order to examine the relative importance of sedimentation for China and Japan, it is important to discuss the underlying preconditions and characteristics of sediment yield. The scale of these values is also supported by the World Commission on Dams, according to which between 0.5% and 1% of the world's total storage capacity is lost on an annual basis (World Commission on Dams, 2000: 65).

Sedimentation rates are influenced by various factors, most notably are the geomorphological composition of the riverbed, the soil composition (sediment type), and the vegetation coverage of the drainage basin. The actual sediment loads of rivers can vary significantly depending on the local specifics. Research indicates that a sediment load of up to 10,000 tons per km² catchment area per year is possible, while minimum values can be as low as 50 tons per km² per year (Alam, 2004: 2). Large sediment loads primarily occur in regions with fine soil composition - mostly found in arid or semi-arid areas. Consequently, sedimentation is not an issue in countries where the riverbeds are mainly composed of rocky granite, such as Canada and Norway, or - to a lesser degree - Japan (Intergovernmental Panel on Climate Change, 2012: 465). China, on the other hand, with its massive loess areas (e.g. along the Yellow River (黄河), is likely to have high sedimentation yields, as shown by map 4.8.



Map 4.8: Global Sedimentation Yield (Walling and Webb, 1996: 8)

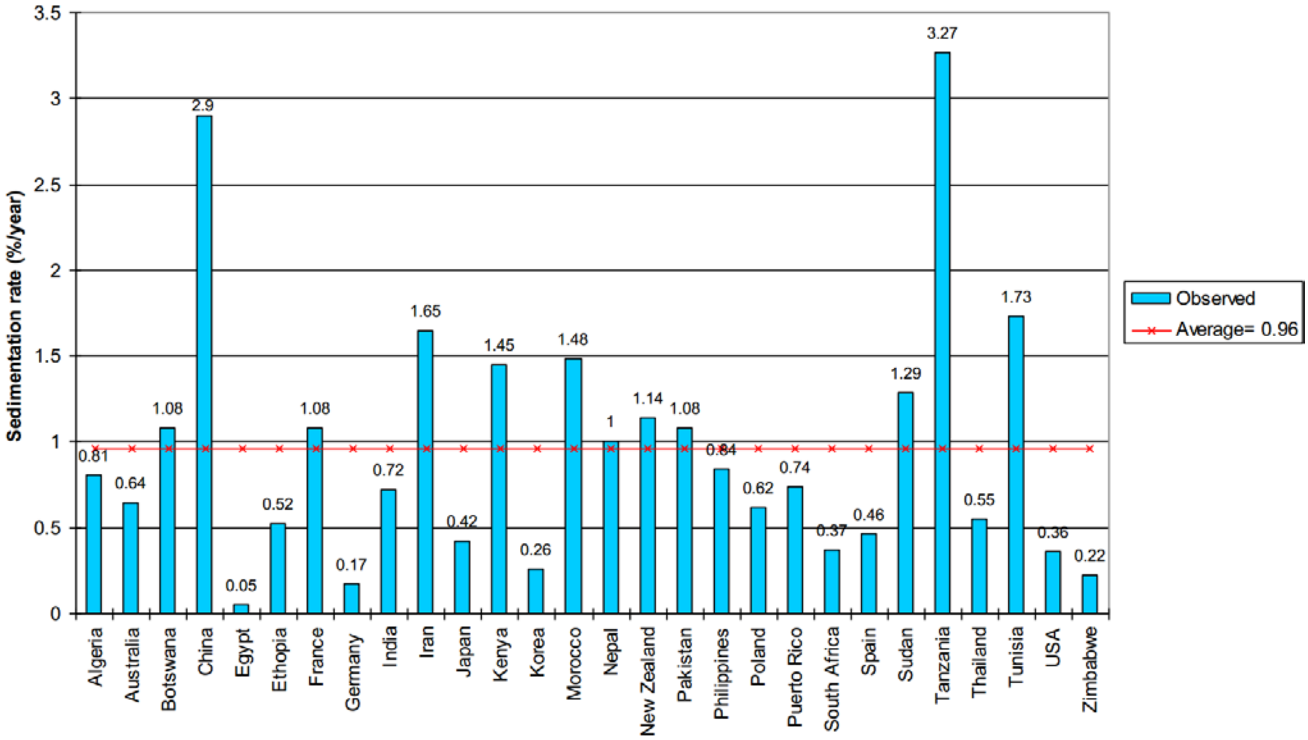
A related factor is the type of sediment prevalent in a region. Sediment coarser than 0.1 mm may greatly accelerate the teardown of turbine parts (Committee on Cost Savings in Dams, 2008: 23). A sediment-quartz-ratio of 85% or higher is for instance considered to be extremely damaging to the turbines and other affected equipment (Committee on Cost Savings in Dams, 2008: 23).

In **China**, dams were initially built to be able to sustain a sediment load of a 100 years timespan. Unfortunately, during the early construction period in the 1950s and 1960s, the estimation for annual sediment load was lower than the actual influx. As a result, several Chinese dams from that period are already overloaded and face serious performance issues. The most known example is the Sanmenxia Dam (三门峡水利枢纽工程), one of the largest of its time, which was completed in 1960 with a height of 106m (Morris and Fan, 1998: 24.21)

As mentioned, fine soil composition usually leads to high sedimentation rates, and China is one of the world's prime examples. According to recent research, Chinese dams are subject to the world's second highest sedimentation rates. Approximately 2.9% of the total Chinese reservoir capacity is lost due to sedimentation on an annual basis (see graph 4.9). This value exceeds the averages for Asia (0.85%) and the world (0.96%) by almost 300% (Basson, 2008), which is particularly noteworthy because the high sedimentation yield is known to Chinese dam designers since the construction of the Sanmenxia dam.

Given the current total reservoir capacity in China of approximately 492 billion m³, a sedimentation ratio of 2.9% amounts to 14.27 billion m³ lost reservoir capacity on an annual basis. To put this value in perspective, the loss equals 6.7 times of the total Austrian reservoir capacity, almost half the Three Gorges Dam, as well as approximately 75% of the whole Japanese reservoir capacity (Food and Agricultural Organization of the United Nations, 2013b).

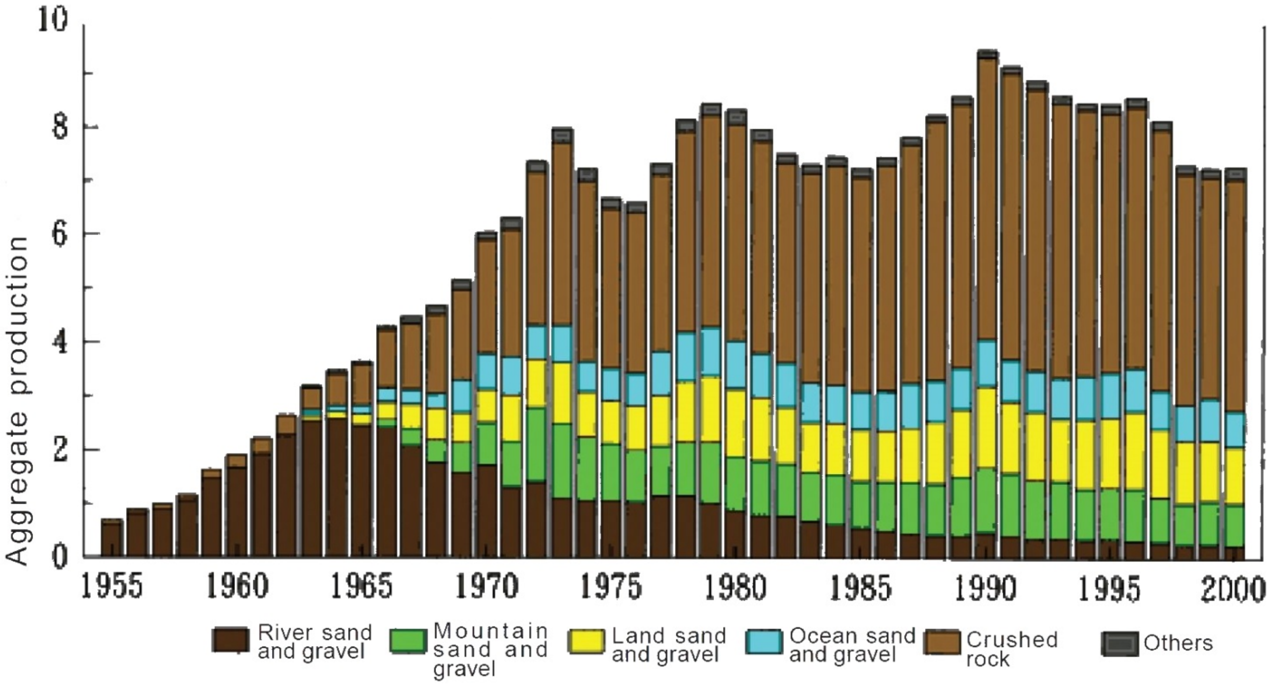
While the composition of Chinese soil is responsible for the country's massive sediment yield, the fine structure ensures that turbines and other mechanical parts of the dam are not severely damaged by the sediment particles. Most of the sediment generated by the Yangtze or the Yellow River is clay based and while the sheer amount poses serious issues, it does not have noteworthy harmful effects on the electromechanical machinery of dams (Yang et al., 2002: 409).



Graph 4.19: Sedimentation Rates by Country (Basson, 2008)

In regards to sedimentation, **Japan** is in a unique position. On the one hand, the soil in riverbeds is very rocky, similarly to Canada or Norway, although to a slightly lesser extent (Intergovernmental Panel on Climate Change, 2012: 465). Such a soil composition indicates a low sedimentation rate (see Graph 4.10). However, there are two factors leading to an increased sediment yield in Japan. Firstly, the ongoing depopulation of intermediate and mountainous areas in Japan has led to an insufficiency in available human resources for effective forest management, leading to a reduction of the environment's natural capability to prevent landslides and ultimately causing an increase of sediment load (Inoue, 2009: 93). Graph 4.10 indicates that this trend has been ongoing since at least the early 1950s.

Secondly, Japan's geographic situation: The country is located on the "Ring of Fire", which exposes it to high tectonic activity (Inoue, 2009: 90). As a result, the geological structure throughout the country is often fragile and bedrocks have been fractured and hydrothermally altered due to the intrusion of volcanic rocks. Due to continuous infiltration, freezing and dissolution of rainwater, as well as bedrock creep, the bedrocks are subject to constant collapse. This causes sedimentation rates to be higher than the soil composition would indicate (Inoue, 2009: 90). The total sedimentation yield in Japan is estimated at roughly 200 million m³. Almost one quarter (45 million m³) of which is trapped in reservoirs throughout the country (Inoue, 2009: 90-91). In comparison to worldwide and Asian average values, the annual sedimentation ration of 0.42% is nevertheless very low (Basson, 2008).



Graph 4.20: Changes in Sediment Composition (Japan) (Inoue, 2009: 94)

In 2005, approximately 34% of the Japanese reservoir capacity was considered to be filled with sediment. This number included 140 dams (equaling 16% of all major dams in Japan, (Inoue, 2009: 93) which have already accumulated the maximum amount of sediment they were constructed for and, as a result, suffer a severe loss in functionality or require massive financial investments to deal with the sediment.

Besides the impact on hydropower stations, there is a second issue that arises from sediment trapping. While not necessarily relevant for every region, the anthropogenic modification to the natural sediment transport can have unforeseen and severe consequences invoked by the lack of sediment supply to downstream and estuary areas. Documented cases include the Nile and Volta Rivers, where hydropower-caused lack of sediment leads to coastline erosion of 5-8 m and 10-15 m annually. For certain areas, at the Nile estuary, up to 240 m of coastline erosion have been documented (World Commission on Dams, 2000: 81). In case of China, it is known that the Yangtze transferred more than 500,000,000 tons of sediment, which caused a coastline extension of up to 50 m on an annual basis. However, this data stem from times before the completion of the Three Gorges Dam, which is expected to trap up to 70% of the Yangtze’s total sediment flow. The consequences, e.g. for cities located at the estuary sandbanks, such as Shanghai, can be significant (Winchester, 1998: 228). Unfortunately, there are no long-term data on this issue or detailed information about similar cases in China or Japan. Therefore, it will not be included in the evaluation.

Conclusion

It has become clear that the burden of sedimentation is completely different in the PR China and Japan. China is faced with a much higher overall sediment yield; Chinese dams experience the world’s second highest sedimentation-caused reservoir capacity loss, which is approximately seven times as high as for their Japanese counterparts, which constitutes an unsustainable situation and a rating of -1.

Japan, on the other hand, has comparatively low total sediment yield, losing only 0.42% of its total reservoir capacity annually. This value is not only below the international average, but also below the 0.5% value that was given by the WCD as the lower end value for sedimentation-caused storage capacity loss. Consequently, the sediment situation in Japan has to be considered sustainable, resulting in a rating of +1.

The sediment composition in both countries partially offset the amount of sedimentation: While the composition in China is very fine and typically does not cause machinery issues, the Japanese sediment composition contains a large share of rock particles, which can damage electromechanical machinery inside the dam. However, the sediment composition must not influence this indicator, as it is already included in the LCOE assessment and would therefore disturb the assessment.

4.3 Social Indicators

4.3.1 Safety

Safety Regulations and Management

Due to the geographical situation, most importantly the high probability of tectonic activity, there are significant risks for the safety of hydropower stations in both China and Japan (Wang, 2009: 147). Therefore, vigilant safety regulations and their implementation are of high importance to guarantee the safety of the countries' citizens.

China's legislative framework regarding hydropower safety is structured in the following way: Authority over dam safety is distributed over two horizontal levels and three vertical levels. On the horizontal level, it is allocated according to the main function of the dam. Dams which are primarily tasked with electricity generation are overseen by the respective branches of the State Grid Corporation of China (国家电网公司), formerly State Power Corporation (国家电力公司), while dams that are mainly used for other purposes such as water management and irrigation are subject to the respective branches of the Ministry of Water Resources (MWR, 水利部). Despite this differentiation, the decision making structures and the general hierarchy are identical in both institutions. On a vertical level, supervision is split between national (for large scale dams), provincial (for medium size dams) and local level (for small scale dams) authorities (Méan et al., 2012: 4-6).

On the national level the Large Dam Safety Supervision Center (LDSSC, 国家电力监管委员会大坝安全监察中心) and the Dam Safety Monitoring Center (DSMC, 大坝安全监测所; formerly Dam Safety Management Center) are also two committees that have direct influence on safety mechanisms and their implementation in particular (Bradlow et al., 2002: 20-22). Shortly after its foundation in 1985, the LDSSC was tasked with the "first round dam safety periodic inspection", a general survey of all major dams in China, which took more than 12 years to complete. One of the main results of this survey was the severe lack of modern monitoring hardware (especially in adequate numbers), software and monitoring and evaluation methods for major reservoirs. To address these shortcomings, the *Dam Safety Monitoring Modification Program of Hydropower Stations* was initiated in 1992, which solved most of these issues over the course of the following eight years (International Water

Power and Dam Construction, 1999). By 2013, all major dams in China were equipped with automatic monitoring mechanisms. Additionally, the LDSSC implemented regulations for annual inspections of dams in 1997 and initiated a second iteration of the dam safety periodic inspection in 1999 (International Water Power and Dam Construction, 1999).

The DSMC is responsible for supporting fund requests in order to finance safety improvements, as well as to act as a technical advisory body to the State Council (国务院). It also formulates general safety instructions and recommendations upon request of provincial MWR branches. For dams which are primarily tasked with hydroelectric power generation, the LDSSC is instead responsible for financial issues (Méan et al., 2012: 5). Inspection and monitoring on site is usually conducted by so called Reservoir Management Units (RMU, 水库管理处), which report to the respective branches of the MWR or the Provincial Flood Control Headquarters (省防汛抗旱指挥部), depending on the dam's scale and primary task (International Water Power and Dam Construction, 1999). The RMU's are also tasked with annual reports regarding potential safety issues and required measures to address them, as well as regular inspections prior to the flood season (International Water Power and Dam Construction: 1999).

While all of the aforementioned national organizations maintain a supervisory and supporting role, the LDSSC has an elevated position in this framework and can be considered the leading actor among the various national organizations since 1999. However, the primary responsibility in regards to monitoring and maintenance of safety lies with the respective dam owner (Bradlow et al., 2002: 20-22).

It has to be noted that the PR China is constantly improving its dam safety regulations. The latest set of planned improvements – made public in July 2013 - concerns large scale dams, in particular the Three Gorges Dam (长江三峡水利枢纽工程) (Xinhua, 2013). These measures aim to reduce dam vulnerability to terrorism by establishing safety control zones for land, water and airspace in the proximity of dams. This includes the banishment of sky lanterns, hot air balloons, unmanned drones and various other kinds of aircrafts in proximity to the dam (Xinhua, 2013). In the light of these regulations and their structure and authorities, China employs international "best practice" in regards to its hydropower safety regulations. (Bradlow et al., 2002: 20-22).

Unlike China, the safety responsibilities in regards to hydropower reservoirs are less broadly distributed in **Japan**. They mainly lie with the Ministry of Land, Infrastructure, Transport and Tourism (MLIT, 国土交通省). In order to enhance professionalism and capacity in regards to regulating dam safety, the MLIT established the Japan Dam Engineering Center (JDEC, ダム技術センター) in 1982 (Japan Dam Engineering Center, 2013b).

In addition to prior existing measures, the MLIT introduced a specific set of earthquake related safety guidelines called *Draft of Guidelines for Seismic Safety Evaluation on Dams*, in order to enhance resilience of Japanese dams in case of earthquakes (Yamaguchi, Kobori and Sakamoto, 2006: 6). A wide variety of factors, which could potentially influence dam stability (such as leakage/seepage, deformation, uplift/pore water pressure, stress, strain and temperature), are measured in accordance with these guidelines. In addition, visual inspections of the dam bodies and foundations are also conducted. The frequency of inspections varies according to the age of the reservoir and is divided between three stages. The first stage covers the construction period until the end of the first impoundment of the dam. During this phase, inspections are conducted on a daily basis for most dam elements. Dams that do not require such frequent reviews (e.g. because of less structural strain due to seasonal weather changes) are assessed on a weekly basis (Yamaguchi, Kobori and Sakamoto, 2006: 3-6). The second stage covers the timeframe from the first impoundment onwards until the dam reaches a steady state (which is typically after three to five years). During this period, inspections are done mostly on a weekly basis. The third and last period begins after the dam reaches a steady state. Reviews are scheduled once per months, while less endangered dams are reviewed on a quarterly basis. Variations might occur in rare cases, depending on the scale and type of the dam. In addition to this, inspections are to be performed on a more frequent basis in case of special events such as floods, earthquakes or unusual performance (Yamaguchi, Kobori and Sakamoto, 2006: 2-5).

These inspections are usually carried out by the dam owner's local operating staff under the guidelines provided by the MLIT and the JDEC (Yamaguchi, Kobori and Sakamoto, 2006: 4-5). In addition to the frequent inspections conducted by local employees of the respective dam owners, the JDEC also conducts reservoir inspections on behalf of the Japanese State. These, however are far more extensive and thorough, and consequently also very time-consuming, resulting in a low average inspection rate of ten dams per year. The JDEC concentrates on reviewing dams which might require special attention due to age (more than

30 years) or due to damage caused by external sources such as earthquakes (Japan Dam Engineering Center, 2013b). During emergency cases, however, the JDEC is able to perform significantly faster than under the regular procedure: In response to the 2011 Tohoku earthquake (magnitude 9.0), over 400 dams were inspected in the subsequent months (Yamaguchi, Kondo and Kobori, 2012: 945-946).

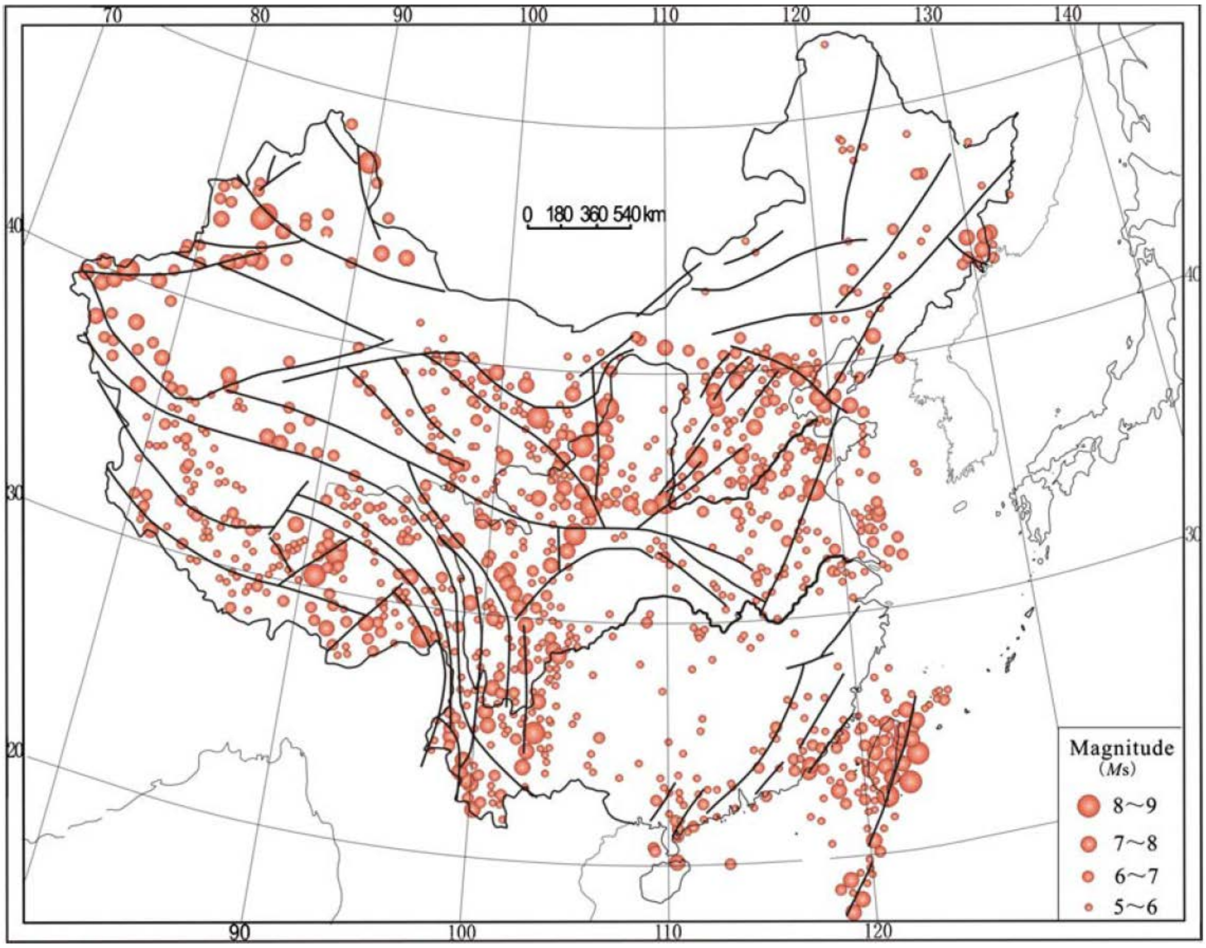
Natural Risk Exposure

Both China and Japan are historically frequently affected by high magnitude earthquakes which have caused significant material and human damage (Wang, 2009: 147). Over the course of the 20th century, **China** has been hit by 15 mainland based earthquakes of magnitude 7 or higher. These led to the death of more than 750,000 people, with the 1976 Tangshan (唐山) earthquake (magnitude 7.8) and the 2008 Wenchuan (汶川) earthquake (also commonly referred to as the Sichuan earthquake, magnitude 7.9) being the most devastating as of yet, causing 240.000 and 88.000 deaths respectively. Tectonic activity in China is mostly caused by northwards movement of the Indian Plate, which strongly affects western and southern China (excluding the country's south east). As a result, this area is also highly saturated with seismic fault lines. Another area of important seismic movement is China's north-west, where the Pacific Plate is sub-ducted by the Eurasian one, leading to "stretching" and the formation of fault movements and occasional high magnitude earthquakes (Wang, 2009: 147).

Given these prerequisites, that hydropower stations in China face a high danger of being damaged or even destroyed as a result of earthquakes and tectonic movement and, as a result, cause major damage to humans and structures not only in their immediate proximity but also further downstream due to potential floods caused by a dam breach.

However, as map 4.2 shows, epicenter locations in China are highly concentrated in central and western China. Data from the China Earthquake Administration (中国地震局) suggests that roughly 82% of high magnitude earthquakes in recent times occurred in south-west China (cited in Chen, 2004: 1).

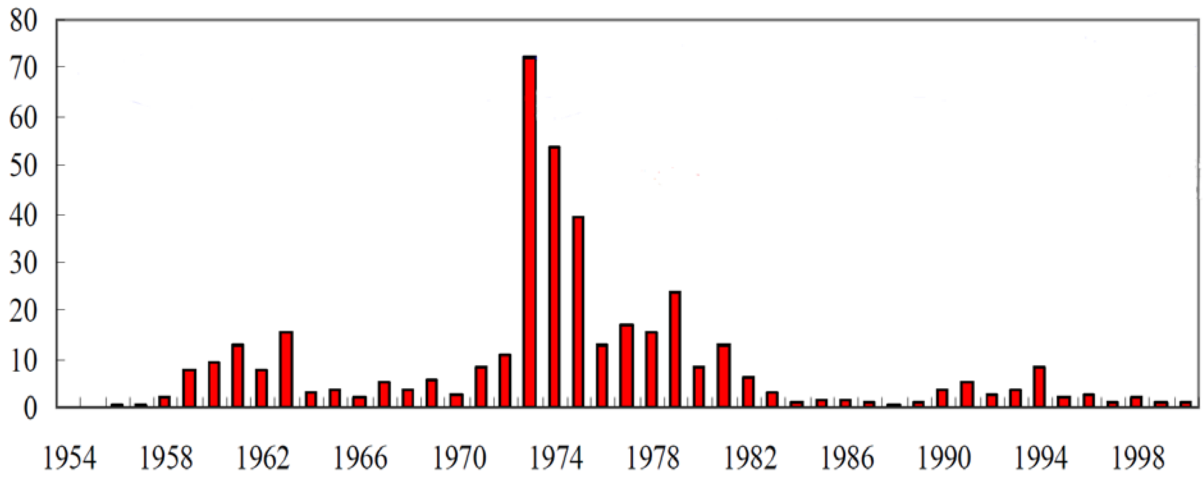
While this area comprises the vast majority – approximately 80% - of the country's economic feasible hydropower potential, the PR China has so far been reluctant to increase hydropower development in these regions – the utilization ratio accounted for only 10% in 2004 (Chen, 2004: 1).



Map 4.21: Earthquake Epicenter Distribution China: 2300 BC – 2000 AD (Wang, 2009: 147)

On the other hand, in the course of the recent resurgence of hydropower development in China, several large scale dams are in construction in areas with high earthquake frequency, such as Xiaowan (小湾坝), Maji (马吉拱坝) and Nuozhadu (糯扎渡大坝）at the Mekong River（湄公河), Songta（松塔坝）at the Nu River（怒江）or Xiangjiaba（向家坝）and Xiluodu（溪洛渡大坝）at the Yangtze（长江）(Beitarie, 2011). However, although the dams took significant damage, even the 7.9 magnitude Sichuan earthquake in 2008 did not lead to dam breaches at the closest major dams (Zipingdu 紫坪铺水利枢纽 and Bayi 八一水库溃坝, located as close as 17km and from the epicenter; Méan et al., 2012: 5).

A significant improvement since the 1970s can be observed regarding the Chinese dam breach ratio. Ever since the establishment of the LDSSC, dam safety in China has increased as shown by the following chart:



Graph 4.22: Annual Dam Breach Ratio in China (in %) (Dam Safety Management Center, 2008: 4).

This positive trend has continued, with the annual dam breach ratio decreasing to 0.06% in 2008, which is significantly below the worldwide average of 0.2% (Dam Safety Management Center, 2008: 5). While the 2008 Sichuan earthquake (magnitude of 7.9) did severely damage the closest hydropower dams (Zipingdu and Bayi), a breach did not occur. Given the close proximity of only 17 km between Zipingdu and the epicenter, the safety performance of these plants can only be judged as very well given the extraordinary stress they experienced.

The situation in **Japan** is similar: there is a realistic threat of seismic-caused damage to dams which could potentially lead to major dam breaches. The country is even more affected by earthquakes than China. Given its location on the "Ring of Fire" it is virtually surrounded by tectonic plates, which bear a constant risk of major earth- and seaquakes. Further, there is also a large amount of fault lines in Japan as well as its close proximity (Sakamoto, 2002: 12). Moreover, the majority of Japans large scale hydropower stations are located at the central part of the mainland in the Kanto (関東地方) and Chubu (中部地方) regions, which are very close to the major fault lines along the Itoigawa-Shizuoka (糸魚川静岡構造線) and Tanakura (棚倉構造線) tectonic lines (Terashima, 1988: 40).

Despite this high exposure to earthquakes, there is no information available to the author that would indicate any noteworthy performance issue such as dam breaches. A single exception is the Fujinuma the Fujinuma Dam (藤沼ダム) in Fukushima prefecture (福島県), which was damaged during the 9.0 magnitude Tohoku earthquake in 2011 (東北地方太平洋沖地

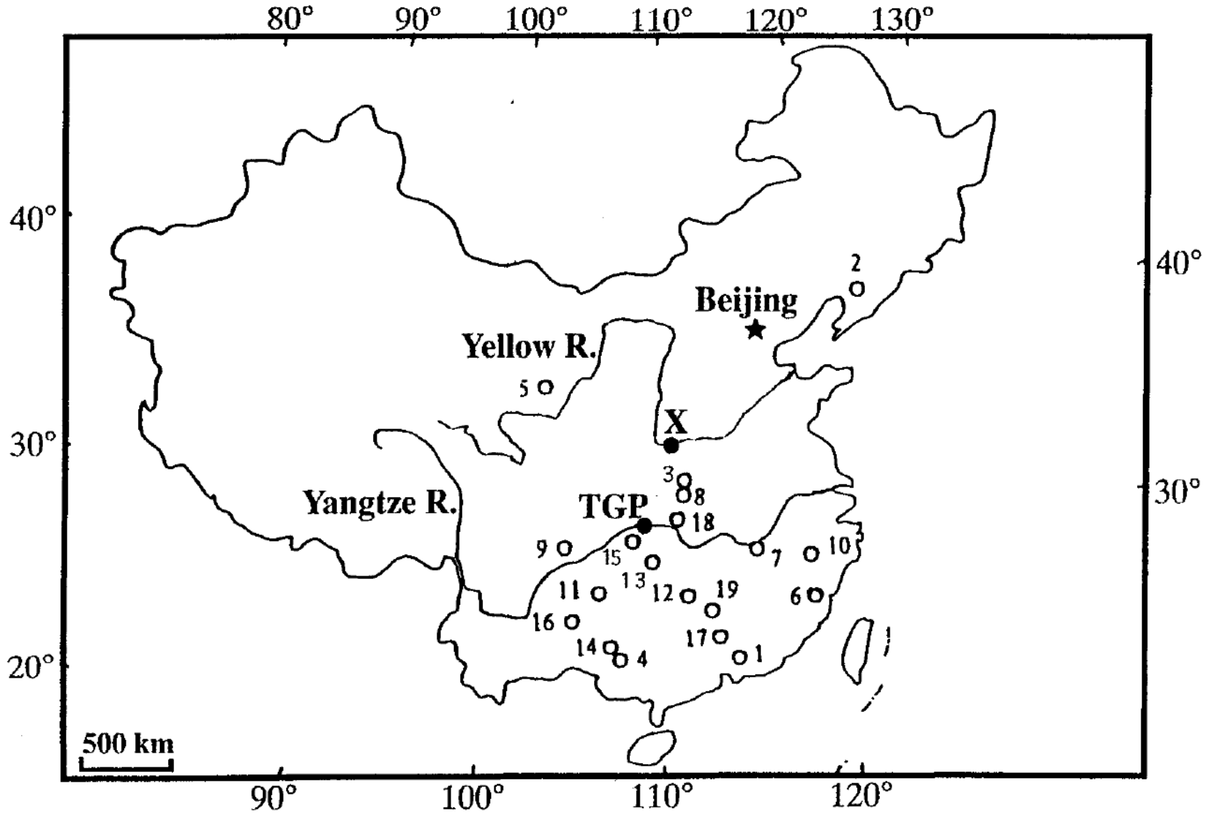
震). The resulting breach, however, was only minor and did not endanger the overall structural integrity of the dam. Considering the structural damage suffered by to other structures in similar proximity to the epicenter, as well as the rarity and intensity of a 9.0 magnitude earthquake, the dam's seismic related safety can be considered excellent (Pradel et al., 2012: 1-4).

Reservoir Induced Seismicity

The issue of seismic safety is two-fold. The first form is caused by hydropower reservoirs themselves: Reservoir Induced Seismicity (RIS). Harsh K. Gupta defines RIS as "*earthquakes occurring in the vicinity of artificial water reservoirs as a consequence of impoundment.*" (Gupta, 2002: 280). The pressure that is exerted on the ground by the large amounts of reservoir water leads to cracks and fissures in proximity of the reservoir. Additional stress through the variation of water levels, e.g. during large discharge periods or heavy inflow can amplify this effect, which most likely results in enough tectonic tension to cause earthquakes (Gupta, 1992: 192-193).

It has to be noted that the process of RIS is not yet fully understood. However, the general concept is undisputed, as there have been many studies that clearly prove a causal relation between seismic activity and major water level fluctuations in large reservoirs (Probe International, 2008).

In **China**, 19 past earthquakes are considered proven occurrences of reservoir induced seismicity with a magnitude ranging between 2.2 and 6.1. The most severe of these was the Xinfengjiang (新丰江) earthquake of 1962 (magnitude 6.1) (Chen and Talwani, 1998: 136-138). While it is not yet common consensus, there are several experts (including government professionals, such as Fan Xiao (范晓) of the Sichuan Geology and Mineral Bureau (四川省地质矿产勘查开发局), who attribute the 2008 earthquake in Sichuan (四川省) to RIS. With a magnitude of 7.9 and approximately 88,000 deaths this would be by far the world's most severe RIS earthquake (范 Fan, 2012; Naik and Oster, 2009).



Map 4.23: Location of Proven RIS cases in China (Chen and Talwani, 1998: 134).

Given that China is currently constructing more large scale hydropower stations in areas with high earthquake probability, it is likely that reservoir induced seismicity will become an even more severe problem in the future (Chen, 2004: 1-2).

Furthermore, China is – by far – the world's most affected country in terms of RIS. While 19 proven cases might not seem to be a lot, it is notable, that the 2nd highest position in this list is currently held by the United States with only 5 cases. The reason lies in the combination of high seismic activity and the large average scale of Chinese hydropower plants (Probe International, 2008).

Japan, on the other hand, while also being highly affected by potential earthquake risks and seismic activity, has only recorded one proven case of RIS with significant magnitude: the Kurobe (黒部) earthquake of 1961 with a magnitude of 4.1 (Probe International, 2008). A study conducted by the Kobe University's Department of Earth Sciences assessed 81 major dams which were considered large enough to cause RIS (with a dam height of 80m and above). The analysis showed that 13 dams have caused cases of RIS after the impoundment, but also one case in which seismic activity was actually reduced. However, these measurements were conducted with highly sensitive equipment, and with the exception of Kurobe, none of those cases reached a noteworthy magnitude (Terashima, 1988: 35-38). In addition, leading RIS scientists rarely discuss Japan (e.g. Gupta, 2002; Talwani, 1998).[14]

Conclusion

While the two legislative frameworks regarding safety are difficult to compare due to their inherent divergence in scope, emphasis and contents, the analysis has shown that China and Japan both have extensive legislation and dedicated central governmental structures that are responsible for oversight and enforcement.

The risk situation in China and Japan is roughly comparable. Both countries are located in areas of very high seismic activity and tectonic movement. They have been subject to massive earthquakes in the past and will continue to be in the future. The majority of Japans large scale hydropower stations are located in the Kanto and Chubu regions, which are located above large fault lines. The chances of these plants being hit by earthquakes are as high as nowhere else in the country. China, on the other hand, has so far avoided to construct large scale hydropower stations in the areas which are most affected by earthquakes (e.g. upper Mekong region). However, given the increased hydropower development of recent years, construction of several large scale plants in these areas has begun.

Despite the high exposure to earthquakes, dams in both countries have been performing remarkably. Even during the 2011 Tohoku and 2008 Sichuan earthquakes, there have been no major dam breaches.

China is the country with the world's highest amount of proven RIS cases, most likely due to the combination of a highly active seismic foundation and the large average scale of Chinese hydropower plants. RIS in Japan, on the other hand, is almost negligible, most likely because of the lesser reservoir area of Japanese hydropower plants. With two and three positive parameters respectively, the situation has to be considered sustainable in both, China and Japan and will therefore be rated with: +1.

[14] A more detailed overview of proven major RIS cases can be found in table 1 of the appendix.

4.2.2 Community Engagement

Lacking acceptance of a hydroelectric power project among the affected communities is one of the few factors that can possibly put a halt to the construction of a site even if national and local politics as well as the acting business partners are keen on going through with the construction. At the same time, it is a factor that has traditionally been overlooked by decision makers, underestimated or even completely neglected (Ho, 2001: 897-900).

The relationship between central government of the **PR China** and non-governmental civil movements (such as NGOs) has traditionally been rather complicated. In recent years there has been a notable improvement of this situation (Ho, 2001: 903-906). While mutual distrust is still prevalent, in a few select sectors, such as environmental protection and healthcare, NGOs have been allowed to grow since the early 1990s. Between 1992 and 1995, the number of environmental NGOs more than doubled (from 4 up to 9). In the following year, 1996, this number doubled again to 18, with an equivalent surge in employees and members (Ho, 2001: 901).

Despite this progress, the influence of social movements on the outcome of (hydropower development) decision making processes in China is still very limited, as the following case studies will show. They relate to the construction of the Three Gorges Dam (TGD, 长江三峡水利枢纽工程) and the Pubugou Dam (瀑布沟大坝), which were chosen as examples because they had invoked the two largest cases of civil movement against hydropower development in China as of yet (Gleick, 2009a: 97). Additionally, the construction of the Pubugou Dam began in 2004, a time at which the TGD's construction was already completed to a large degree. Therefore, these two cases do not only show a very recent state of the matter in China, but can also display potential development and trends in regards to the social acceptance and engagement of the hydropower sector over the past two to three decades.

Three Gorges Dam 长江三峡水利枢纽工程

The Three Gorges Dam is the world's largest hydropower station, located in Hubei province (湖北省); it features a generating capacity of 18,000 megawatts, which exceeds the second largest dam, the Itapúa in Paraguay, by almost 50% (China Three Gorges Corporation, 2010). More than one million people had to be relocated during its construction and the filling of its

1045 km² sized reservoir area. Holding various other– positive and negative – superlatives, the TGD was the first project to ever invoke a nation-wide protest movement in the PR China (Ho, 2001: 901).

Prior to the construction‘s commencement in 1994 and during its early phase, there was only limited public resistance, mostly due to the crackdown on opposition in the aftermath of the Tian'an'men incident (四五天安门事件）1989 (Khatun, 2013: 12). Such resistance came from scientists and a few media actors, most notably the journalist Dai Qing（戴晴）. Her book *Yangtze! Yangtze!* 《长江长江》discussed the potential safety issues of the TGD in great detail. The book was banned shortly after publication and Dai Qing was later imprisoned. Nonetheless, the opposition from intellectuals and experts continued: In March 1998, a group of TGD construction specialists tried to convince the central government to abandon plans for an increase of dam height to 156 meters. They argued that the increased height would cause unforeseeable risks. Their pledges were ignored and even though similar objections were subsequently raised by other groups as well, the dam height was even increased a second time up to the final 181m (Lin, 2007: 167).

As the construction progressed and an increasingly number of people was resettled, protests arose among the affected citizens. Lack of economic security and support, insufficient resettlement policies, corruption in resettlement payments and shortage of land in the resettlement areas were the main reasons for these protests (Jing, 2000: 144).
The first large-scale demonstration took place in 1997 in Gaoyang Township（高阳镇）, Hebei Province (河北省). More than 10,000 rural residents tried to gain attention for their petitions from the central government (Jing, 2000: 144). After initial success two leading petitioners were accused of having taken part in the Cultural Revolution and were banned from further engaging in any TGD related matters. An additional crackdown campaign launched by local officials (“laws and village security campaign”) finally led to a halt of this protest series (Jing, 2000: 144). Nevertheless, smaller protests occurred on a regional basis, although they had little to no positive result. Several group leaders were imprisoned (Khatun, 2013: 12). Except for the dismissal of two local government officials, all of the Three Gorges Dam protest movements failed to achieve tangible results (Ho, 2001: 901).

Pubugou Dam 瀑布沟大坝

The Pubugou Dam is located in Sichuan province, at the Dadu River (大渡河), a tributary to the Yangtze. It was constructed between 2004 and 2010 and is one of the largest Chinese dams, featuring a generating capacity of 3,300 Megawatts (Vermeer, 2011: 11-13).

During its early construction phase, the Pubugou project faced significant opposition. With several ten thousand protesters the dimension was similar to that of the Three Gorges Dam's construction. Most of the involved citizens were farmers from the adjacent Hanyuan County (汉源县). The affected population was neither included in any decision making processes, nor was there any noteworthy information exchange (Vermeer, 2011: 11-12).

As a result, Pubugou faced very similar problems to the TGD project: Involuntary displacement (of approximately 100,000 people), deficits in compensation payment, shortage of available land in resettlement areas and corruption of local officials. The protests turned violent and the local authorities responded by dispatching several thousand paramilitary police officers. In the subsequent fights civilians were severely injured, many were arrested and one man allegedly died under police custody which in turn led to even more turmoil (BBC, 2006).

Similar to the Three Gorges project, the protest movements did not lead to any meaningful success for the affected citizens. One party official was replaced and the construction work was stopped for several months, but resumed shortly afterwards and in 2010 the Pubugou Dam was finished as planned (Lim, 2004).

In contrast to China, civil society movements had a very alternating role in post-war **Japan**, especially in regards to matters of ecological issues. There was a significant civil movement to fight environmental pollution and the associated health impacts prior to the 1950s and 1960s, a time which is also known as the "phase of ecological ignorance [of the government]" (Weidner, 1986: 5). In response to this massive social pressure, the government changed its position towards those matters in 1970 and adopted a more serious ecological policy (also known as technocratic ecological policy) by introducing legislation that forced the industry to cease polluting its environment with highly toxic wastewaters, unfiltered exhaust fumes etc. (Meves, 1993: 162-175). The new environmental protection legislation and its implementation were highly effective and considered satisfactory by the population. The government did not only solve the existing issues, but also continued to address upcoming ones in a proactive and effective manner. Lacking an ongoing common reason to fight for, the civil movements of the early 1960s/70s dissolved, instead of transforming into a political "green" movement/party as in many other states (Toshiko, 1999: 100-104).

When assessing the social acceptance and community engagement in hydropower development, the Japanese geography has to be taken into account. Most dams in Japan were constructed in mountainous riverbeds that were only sparsely populated. While dam construction had a high impact on these villages, the number of affected people was very low (Takahasi, 2007: 35). Even though there were many cases of local opposition against dam construction, they lacked leverage and mutual exchange and support. Each individual resistance movement fought on its own, which usually resulted in failure. These small-scale uprisings were of little impact for most of the "high phase" of Japanese hydropower development in the 1950s, 60s and 70s (Toshiko, 1999: 100-104).

Following, three case studies are discussed. They deal with the struggle for and against dam construction at the Naka River (那珂川), Nagara River (長良川) and Yoshino River (吉野川). These three cases were chosen because they mark key moments in the transformation of Japans hydropower related civil society movement. Understanding this transformation provides valuable insight into the current state and effectiveness of civil anti dam movements in Japan.

Naka River 那珂川

The Ministry of Construction (MoC, 建設省) proposed the construction of a dam at the upper region of the Naka River, near the village Kito (木頭村) in Tochigi prefecture (栃木県) in the mid-1970s. (Kin, 2006: 104). Opinion on the dam construction was split in the village. On the one hand, a major part of the local population consisted of farmers who were concerned about potential impacts on the local ecosystem and, as a consequence, on the foundation of their livelihood. On the other hand, locals from other economic backgrounds (e.g. shopkeepers, gastronomes) appreciated the construction plans, because they expected their village to turn into a "boomtown" and thereby receiving substantial income increases. The local government was initially in support of dam construction because of the anticipated boomtown benefits. However, the opposing faction fielded its own candidates for city council and village head elections, and due to their group being more numerous, they managed to win the elections. As a result, the local government changed its stance to oppose the project as well. The dam's construction was postponed on an annual basis for more than 30 consecutive years and was ultimately canceled by the MoC because the dam was not considered necessary anymore, due to a changed demand structure. The Naka River movement was one of the very first anti-dam movements in Japan, as well as the most long running one (Kin, 2006: 104).

Nagara River Estuary Barrage Project 長良川河口堰事業

The planning of the Nagara River Estuary Barrage Project dates back to 1973, although construction started as late as 1988. Its importance stems from the fact that it was the first anti-dam movement that achieved nationwide popularity and thereby managed to spark and inspire protest movements in other regions of Japan (Toshiko, 1999: 100).

Unlike during most other anti-dam protest movements, the dam construction at the Nagara River was not opposed by the directly affected local population; there was no fear that the dam would have a negative impact on agricultural production. Instead, the initial opposition came from a loose coalition of kayak and canoe fans, sport fishers and various other groups of watersport enthusiasts. They opposed the damming of the Nagara River Estuary because, at the time, it was one of only two Japanese rivers that were still in their natural state. As such, this specific area of the Nagara River was a natural resort that attracted many tourists and offered multifold recreational options. It was also famous for the high quality of its water (Toshiko, 1999: 100-101).

The opposition group organized a large variety of events, including public forums, dialogues with dam proponents and government officials and conferences with international experts. Their public relations campaign was so successful that it did not only gain massive attention in all of Japan, but even managed to raise international awareness (Kin, 2004: 102-105).

Due to the extensive media coverage, experts and various interest groups joined the public debate and the Nagara protest movement received massive support, e.g. by a petition through which 2,200 university scholars demanded the cancellation of the dam's construction. It was the first time in the history of Japanese hydropower development that a dam construction received this degree of attention and fostered a broad discussion about the advantages and disadvantages of hydropower on various levels (Kin, 2004: 102-105).

In December 1990, the movement even reached partial success, as the Director General of the Environment Agency stated that "the estuary dam had the possibility to increase the danger of flooding and to do harm to the ecology of the river" (Toshiko, 1999: 101). However, despite all of its successful mobilization efforts, the Nagara movement was not able to put a halt to the project: Construction on the Nagara River Estuary Barrage Project continued and was completed in 1995 (Takahasi, 2007: 43).

Nevertheless, the movement significantly influenced future anti-dam campaigns in Japan. It showcased that opposition was a viable option and it provided its successors with a vast amount of experience and knowledge to build on. It also acted as a stimulus to enliven new campaigns against dam construction projects all over Japan, such as on the Sagami River (相模川), the Hida River (飛騨川), and the Yoshino River (吉野川). The campaign against the Nagara River Estuary Project served as a model for new activities in this area, while facilitating the development of networks among activists to exchange information and collaborate in their initiatives (Toshiko, 1999: 100).

Yoshino River 吉野川

In the 1990s, the Ministry of Construction issued a proposal for dam construction at the Yoshino River Estuary, near Tokushima City (徳島市). The majority of the local population opposed the construction. Having learned from the Nagara River movement, they formed a committee which hosted various dialogues, public forums and similar events. The committee's main task was to provide the population with all available information and facts related to the dam construction project, enabling the people to make an informed decision on whether or not to oppose the project. When it became clear that the majority of the local population opposed the dam, the committee tried to initiate a referendum. This was initially blocked by the local government, but increasing public pressure succeeded, leading the city council to drop the blockade. Approximately 55% of Tokushima's population took part in the vote with an end result of over 90% opposing the dam. On this basis, the local government decided to postpone the dam construction infinitely. Up until now, there has been no dam built on the Yoshino River Estuary (Kin, 2006: 105).

Conclusion

Between the 1970s and 1990s, China and Japan both have had a history of weak social movements which were completely unable to sufficiently lobby for the interests of the local population. Hydropower related projects were no exception and, as a result, the needs and objections of the affected communities were hardly ever of relevance to the decision makers.

In the case of Japan, this has changed substantially. Through the accumulated experience of the Nagara River case and learning from various other unsuccessful movements, the Japanese anti-dam activists have become very proficient at lobbying for their cause. The Japanese movements typically utilize their country's democratic structures to fight projects and there are no reported cases of major (violent) clashes between anti-dam activists and law enforcement units. As a result, the Japanese central government and the ministries responsible for hydropower development (MLIT and MoC) have come to the conclusion that there is no point in fighting for hydropower projects in cases where a strong opposition is present among the affected population, resulting in the Japanese government completely stopping hydropower development along major rivers and their tributaries in 2004. The Ministry of Land, Infrastructure and Transport cited decreasing demand, outdated projects and most importantly, increasing citizen outcry as the reasons (Kin, 2004: 106).

Community engagement and inclusion during the planning and construction phase in Japan is sufficiently developed. It has been shown that in cases where the population is vastly opposed to a hydropower project, the construction can usually be canceled or at least significantly delayed. Therefore, Japan has to be considered sustainable regarding *Community Engagement*, resulting in a rating of +1.

In the case of China, it could be argued that the situation improved and worsened at the same time. On the one hand, affected communities are much more active and outspoken when it comes to fighting for their interests. However, this positive development has to be seen in the context which made it necessary in the first place: the complete lack of inclusion and community engagement. Despite their large scale and intensity, the protests against two of the most important hydropower projects of the past decades were not able to impact the construction substantially. Also, comparing the citizen's response to the TGD construction, which started in 1994, with the construction of the Pubugou Dam, which started 10 years later in 2004, the most noteworthy development is the violence with which local authorities and protesting civilians opposed each other. Therefore, the practice in the PR China has to be considered unsustainable, resulting in a rating of -1.

4.3.3 Involuntary Displacement

Involuntary Displacement in the course of hydropower station construction can cause a multitude of problems, not only for the displaced population but also for their new host communities. Unfortunately, the potential trickle-down effects are hardly foreseeable and therefore very difficult to prevent. In addition, the sheer amount – often thousands or even tens or hundreds of thousands - of people affected by involuntary displacement makes the issue highly important. In China alone, more than 20 million people have been displaced as a result of hydropower development over the last decades (Terminski, 2013: 11-15). Due to these reasons, the majority of experts consider it to be the most significant problem out of the whole spectrum of social issues arising from hydropower development (Cernea, 2004: 5). However, the displacement process itself is not the only problem - as Cernea argues: "it is mainly a problem of content" (Cernea, 2004: 8). What happens to the people after the displacement is also of importance: In most cases, the living standard is significantly worse than prior to the resettlement.

Additionally, the problems caused by Involuntary Displacement are often amplified by the fact that it receives little attention and its impacts are continually underestimated during the technical planning stages of a hydropower project. Adams identified several issues that are prevalent during hydropower development in this context. Firstly, the pre-construction field investigation is not considering the complete inundation area and is therefore lacking assessments of potential issues or tensions in resettlement areas. Secondly, the process of project appraisal usually leaves not enough time to plan effectively. Moreover, technical experts tend to underestimate socio-economic planning, which often leads to exclusion in the initial construction plans. Thirdly, population surveys, inventory of property and land and the search for suitable resettlement zones are all very complex tasks during resettlement planning. In most cases, these data cannot be gathered in the given timeframe. Lastly, the costs of resettlement are often underestimated, leading to an implementation with insufficient resources, which in turn causes multiple subsequent problems. For these reasons, it is often claimed that resettlement becomes a "paper exercise" (cited in: Chan, 2004: 90).

While usually assessed in a combined way, due to their interconnection, involuntary displacement actually refers to two different processes. The first one is the displacement and resettlement of affected populace, the act of moving them from their origin to their new host areas. The second process is the restoration of their livelihoods. This involves compensation and rehabilitation measures aimed at integrating the resettlers into their new host communities in order to guarantee that neither the resettlers' living standard is worsened by the process, nor that their arrival induces other kinds of socio-economic problems in their new communities (Truchon and Seelos, 2004: 1-3). These two parts of involuntary displacement are accounted for by the approach established in chapter 3.6.3, according to which the first part is measured by the total amount of citizens that have been displaced, while the second part is assessed through the analysis of the respective legal framework and its implementation.

Between 1949 and 2010, approximately 22.8 million people have been displaced in the course of hydropower development in **China** (Hensengerth, 2010: 15). Since then, several other hydropower plants with significant reservoir areas have been constructed, which involved the displacement of a large amount of people, e.g. Daguangba (广坝农场), Dongjiang (东江大坝), Ertan (二滩大坝), Jinping (锦屏一级大坝), Longtan (龙滩大坝), Three Gorges (长江三峡水利枢纽工程), Wuqiangxi (五强溪大坝), Xiaolangdi (小浪底水利枢纽工程) and Xiaowan (小湾坝) (Food and Agricultural Organization of the United Nations, 2013b).

While most Chinese dam construction sites required the displacement of people, two dams stand out because of the high number of displaced people: The Three Gorges and Xiaolangdi dams led to the displacement of approximately 1.3 million and 200,000 people respectively. Those two projects were chosen as case examples because of their inherent differences that will be explained below, while the majority of other hydropower projects in China lie between those two "extremes" (Cernea, 1997: 22).

Given the Chinese government's intention to continue the expansion of the hydro energy sector (Hong et al., 2013: 1533; 中华人民共和国国家发展和改革委员会 National Development and Reform Commission, 2007; Pan, 2005), it is likely that there will be many more cases in which a significant amount of people have to be displaced.

Legal Situation

China's first set of resettlement regulations was compiled and implemented by the Ministry of Finance and Power (MFP) in 1981. Its core mechanism was a set of reimbursement regulations for resettlers, financed by a state fund to which hydropower companies had to contribute 1 RMB per 1000 kWh of generated electricity (Hensengerth, 2010: 13). On request of the State Council, the Ministry of Water Resources initiated an extensive study on the conditions of resettlers in 1984. This study became the starting point for lengthy and ongoing reforms in order to improve the situation of hydropower resettlement (Hensengerth, 2010: 17-18).

Major stepping stones in this reform process were the *Rules of Land Compensation and People Resettlement in Medium and Large Hydraulic and Hydroelectric Projects* (大中型水利水电工程建设征地补偿和移民安置条例, 1991), the *Capacity Building for Natural Resource Legislation* (1996) and the revision of the 1986 *Land Administration Law* (中华人民共和国土地管理法, 1999) (Hensengerth, 2010: 25).

As of yet, the 2006 revision of the 1991 *Rules of Land Compensation and People Resettlement in Medium and Large Hydraulic and Hydroelectric Projects* constitutes the latest and most comprehensive hydropower resettlement framework. It further emphasized the direction set by the revised *Land Administration Law* (1999) – to at least preserve the pre-settlement standard of living - through extending the time period in which resettlers are supported by governmental funds to up to ten years. This is especially relevant in the context that in China, people affected by hydropower displacement are typically dwellers of small, financially weak and lowly developed farming communities (Cernea, 2004: 5). In addition, various other improvements were made to enhance support for displaced citizens: For instance, financial support alone was not considered sufficient anymore, instead, resettlement projects had to provide plans for mid- and long-term economic development of the resettlement area (Hensengerth, 2010: 19).

The compensation mechanisms were refined and more specified as well, according to four different types:

- Land compensation payments
- Resettlement fees

- Compensation payments for ground attachments and young crops
- Special compensation if the expropriated land was used for vegetable agriculture (Hensengerth, 2010: 25)

While the revisions of the *Land Administration Law* and the *Rules of Land Compensation and People Resettlement* contributed significantly to improving the situation for resettlers from a legal point of view, this progress was hollowed out by a restructuring of the resettlement-related responsibilities. The National Development and Reform Commission (NDRC, 国家发展和改革委员会) would continue to develop the general plans for the financing and the implementation of resettlement during major projects. The actual execution of those plans, however, was transferred to local authorities. This significantly increased corruption, which became one of the most important problems of Chinese hydropower resettlements (Hensengerth, 2010: 25).

Further, critiques of the 2006 bills argue that many regulations are too unspecific. For instance, they do not provide guidelines for the compensation of victims of indirect flooding, for instance in cases where residential buildings remained unaffected during the flood, but the flooded crops led to poor harvest (Hensengerth, 2010: 25). Additionally, the 2006 legislation enables resettlement of people far away from their home areas, potentially leading to social and economic problems because integration becomes much more difficult (中华人民共和国中央人民政府 The Central People's Government of the People's Republic of China, 2006).

Three Gorges Dam 长江三峡水利枢纽工程

During the construction of the Three Gorges Dam, between 1994 and 2012, more than 1.3 million people had to be displaced. A total of 14 counties, 140 towns, 326 townships and 1351 villages were affected by the flooding, leading to an estimated loss of 26,500 ha of farmland (Ponseti and López-Pujol, 2006: 178).

Displaced people were resettled to an area covering 19 counties and 5 cities and reaching as far as 360 kilometer further upstream to the city of Chongqing (重庆市) as the most Western point of the resettlement zone (Jackson and Sleigh, 2000: 229).

The amount of people displaced for the Three Gorges Dam overshadowed everything that China (or any other country) had experienced until that point and ever since. Since China had already experienced several conflict-ridden cases of hydropower-based displacement prior to the TGD project, the central government formulated a “development-oriented” resettlement policy for the construction of the TGD in 1993 (Khatun, 2013: 13). The core idea was that displaced people should be resettled within their respective counties, thereby making integration into or the formation of new communities less problematic. This so called “up-slope relocation” aimed to develop new living grounds for cultivation and industries on previously uninhabited land (Yuefang and Steil, 2003: 425).

This approach was, at its time, the most resettler-friendly one employed in China. Nonetheless, it could not prevent a large number of problems. The first one is that resettlers were relocated to upstream areas. Therefore, they suffered from the dam construction by being forcibly relocated, while at the same time being unable to benefit from its positive effects such as improved water and power supply, irrigation or flood control, because those are typically limited to the downstream areas of the respective hydropower station (Chan, 2004: 62-63).

The second major problem was the lack of sufficient monetary compensation due to corruption. Clear rules were in place about how compensation should be handled: A monthly stipend was to be paid. The total amount intended for that purpose was 7.15 billion USD, which amounted to approximately 5,500 USD per person in average (Hvistendahl, 2008:1). However, these rules were – at best – only partially implemented. Countless reports of embezzlement and corruption regarding these funds have been published. A study by Gleick mentions a large number of resettlers who allegedly received nothing at all, while many more received as little as 7 USD per month (Gleick, 2009b: 145).

The third major problem is very similar to the lack of compensation, as it was also caused by corruption: the land provided for resettlement was of highly insufficient quality. The land flooded by the reservoir was considered to be among the most fertile in all of China. The land made available by up-slope relocation, on the other hand, was rock-strewn and far less fertile. Some experts argue that only 300 of the 3655 ha available for resettlement could be used for agricultural purposes at all (Strand, 2000). Reports suggest that officials simply lied to the local population, promising them similar or higher living standards in their new communities, as intended by the new resettlement design plan used for the TGD. Given that approximately 40% of the displaced people were farmers, the loss of arable land combined with the reduced fertility of the land had a strong economic impact on their lives (Strand, 2000).

This led to a large amount of excessive labor force available in the resettlement zones. Because of their insufficient education levels and the lack of established social networks, many of the resettlers were not able to transition into other jobs. Prior to displacement, laborers have been working 227.4 days per year. After relocation, this average decreased by almost 30% to 165.7 days annually. For farmers, the drop is even more apparent: from 209.5 days down more than 50% to 99.4 days per year. As a result, the average per capita income of migrants decreased by approximately 29%, from 3,431 RMB per month to 2,450 RMB per month (Chen and Liu, 2008).

Embezzlement did not only affect the resettlement funds, but also the budgets for the construction of new infrastructure. Chan cites resettlers who claim that the situation was even worse than in most reports. He refers to cases in which not even drinking water was available in the resettlement zones, forcing people to collect rainwater instead (Chan, 2004: 84-86).

Xiaolangdi Dam 小浪底水利枢纽工程

The Xiaolangdi hydropower station is situated on the Yellow River (黄河) at Jiyuan (济源) in Henan (河南省), central China. Construction began in 1991 and it took 10 years to achieve full operational status. Approximately 200,000 people (mostly rural) have been relocated during construction, making Xiaolangdi China's second largest hydropower project in terms of displaced population, second only to the Three Gorges Dam. In total, people from eight counties with 29 towns and 174 villages had to be relocated (Shi, Su and Yuan, 2006: 2).

For the following reasons, Xiaolangdi is worth analyzing and comparing to the TGD. Firstly, it was the second largest case of hydropower related displacement in China. Secondly, the Xiaolangdi construction was partially financed by the World Bank, which had significant implications: By relying on World Bank funding, the project had to comply with the World Bank's rule set, which includes resettlement regulations that are catering towards the affected people. While the general responsibility and authority over the project lay with the Ministry of Water Resources, the World Bank created an advisory panel for environmental and resettlement issues (Hensengerth, 2010: 35).

The World Bank's principles on involuntary displacement procedures during hydropower development were first developed in the 1980s and incorporated into the *Social Issues*

Associated with Involuntary Resettlement in Bank-Financed Projects document. They were revised in 1990 and 2001 as the “Bank Procedures 4.12” and evolved around the core idea that “*benefits are shared between the operator and the communities affected, including relocatees and host communities*” (Hensengerth, 2010: 34). To achieve this goal, resettler rehabilitation measures should be directly connected to benefits created by the project (van Wicklin, 1999: 234-235).

The World Bank approved two construction stages as well as a resettlement project for both stages. Accordingly, in the general organizational structure of the Xiaolangdi construction, resettlement was handled as a separate project with its own independent budget. This organizational separation of budgets made embezzlement more difficult and thereby reduced its impact significantly (Hensengerth, 2010: 22). In order to support the integration of the displaced population, the resettlement project included significant infrastructure measures, such as housing for 276 villages and ten towns, reservoir based irrigation infrastructure for 7000 ha as well as the establishment of more than 300 companies to create more than 20,000 jobs for relocated people (van Wicklin, 1999: 238).

Another difference to the Three Gorges Dam management was that the World Bank required the local authorities to conduct an extensive socio-economic survey in order to study the expected loss of land and property. The survey came to the conclusion that the majority of resettlers are farmers with no sufficient skills to take up other kinds of work - a situation similar to the Three Gorges area. As a result, the resettlement plan concentrated on establishing resettlement areas on an agricultural basis. (Shi, Su and Yuan 2006: 43).

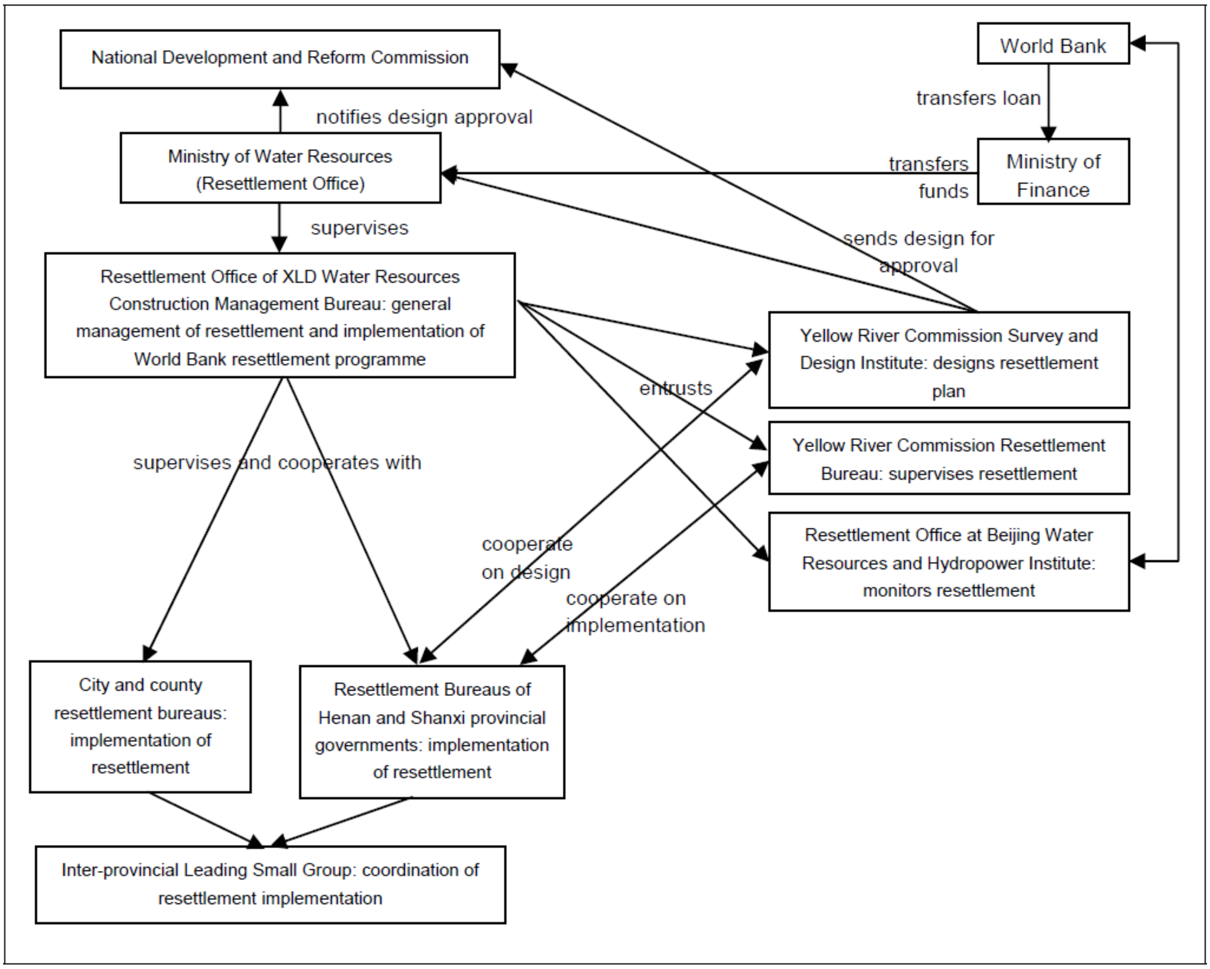


Figure 4.24: Structure of Resettlement Management (Xiaolangdi Dam) (Hensengerth, 2010: 25)

Contrary to the Three Gorges Dam, where the resettlement areas were as far as 360km away from the respective hometowns, the Xiaolangdi resettlers were mostly relocated within a 20km radius, mainly to Xin'an county (新安县) and around the city of Wenmengtan (温孟滩). Many of them were also relocated further downstream, so that they could benefit from the dam features. Each resettler was, in average, provided with 667 m² of arable land. The exact amount varied according to the fertility, which was also assessed during the socio-economic survey, in order to grant everyone the same basic foundation in terms of agricultural potential (Shi, Su and Yuan, 2006: 45-49).

To guarantee that the redistributed land in Wenmengtan was sufficiently fertile, the World Bank ordered a major river works and soil improvement project as part of the Wenmengtan resettlement plan, which was approved by the State Planning Commission (中华人民共和国

国家计划委员会) in 1993, subsequently executed and completed in 2003 by passing a completion assessment (Hensengerth, 2010: 26).

While the resettlement of the Xiaolangdi project was significantly more resettler-friendly and also much more professionally executed than the TGD, there were still several points of criticism. For the most part, these referred to the lack of interaction and participation opportunities of the affected people. Despite the conduct of public hearings and discussions, in case of real conflict, the village committee was allowed to overrule any objections by the population check (Hensengerth, 2010: 26).[15] In addition, some issues (e.g. minor cases of embezzlement) occurred regarding compensation payments in Xiaolangdi. However, according to reports, these were based on problems during the registration process instead of corruption and were solved shortly after the initial construction period (Chen et al., 2004: 2012).

Resettlement as a result of hydropower development in **Japan** has been entirely different: it was rarely necessary, and if it was, the number of affected people was comparatively low. Over the last three to four decades, there has not been a single major case: In average, less than a thousand people are affected by ID on an annual basis (Takesada, 2009: 419 – 420). Accordingly, there is no information and literature discussing involuntary displacement as noteworthy issue in Japan. As a result, this section will focus on analyzing the legal framework concerning displacement in Japan.

There are three main reasons for the limited amount of displaced people in Japan. Firstly, dams in Japan are usually built in mountainous villages, which are scarcely populated due to urban migration and an ageing demography (Inoue, 2009: 93). Secondly, as was shown in chapter 4.3.2, public resistance against hydropower projects has been fairly successful in recent times, leading to a lot of canceled projects in regions where the population was strongly opposing dam construction. Finally, the compulsory acquisition of land for hydropower development could take several years and even decades in some cases. The legal framework regulating land acquisition during the high-time of Japanese hydropower development in the 1950s and 1960s were the *Guidelines for Compensation for Losses in Acquisition of Land for Public Use*, and after 1966 its successor, the *Guidelines for Public Compensation in Acquisition of Land for Public Use*. These rule-sets were insufficient,

[15] While important to the process itself, this is not included into the evaluation, as it rather belongs to the category of community engagement.

because affected people felt victimized, forced relocation into new host communities led to social problems and local governments often opposed such hydropower construction and the related resettlement plans. This, in turn, led to continued opposition to land acquisition, which significantly prolonged the (pre-) construction phase of hydropower stations and ultimately made hydropower projects economically unfeasible for potential investors (Takahasi, 2007: 39). Population displacement and relocation was therefore re-regulated in the 1972 *Act on Special Measures for Development of Reservoir Areas* (ASMRAD), which tried to solve the issue by making a hydropower developer provide measures to appease to local citizenry. This included the introduced of 14 infrastructure measures a dam developer had to implement before a project could be approved (Takahasi, 2007: 38). Those measures most notably included development of, and ongoing support for public infrastructure (e.g. roads, water supply and sewage systems, public housing, healthcare and welfare). This set of improvements made relocation more attractive for people, which in turn lowered land acquisition times considerably (Takahasi, 2007: 38-39).

A total of 93 dams have been constructed under the ASMRAD regulation, which involved an additional spending of 747 billion Yen (approximately 8 billion USD) for ASMRAD related regional development (Takahasi, 2007: 38) and caused involuntary displacement of 9020 households over the last 37 years (until 2009). With averagely less than 100 affected households annually over the last 15 years (Food and Agricultural Organization, 2013b; Takesada, 2009: 419 – 420), the issue can be considered negligible on a country scale.

In addition to the regulations, several funds in Japan guarantee the smooth transaction of required payments. Most of these funds are subsidized by the Central Government, including the largest one, the *Fund for Reservoir Areas Development*. There are also several other funds organized and financed by dam operators or benefactors (such as downstream communities). Those, however, lack the strong financial and political backing that the central government can provide and are therefore negligible outside of their respective area (Takahasi, 2007: 40).

The purpose of these funds is to stabilize the life of displaced citizens and to support affected areas such as host communities. These activities range from re-employment assistance over ecological preservation projects to the placement of counselors for citizens and sponsorship of events and debates (Takahasi, 2007: 39-41).

Conclusion

The key problem of all reservoir resettlement projects is the unequal allocation of project costs and benefits. In particular, this has been reflected in the case of the TGD. However, even the World Bank-directed construction of the Xiaolangdi dam has displayed significant issues. In general, the TGD seems to be more exemplary for Chinese dam constructions. Stein, for instance, mentions a Chinese study which concluded that, over the past 30 years, only one third of all resettlers managed to keep their living standard after resettlement, while another third was degraded to subsistence livelihoods and the last third fell into poverty (Stein, 1998: 8). Nevertheless, the Chinese authorities have learned a lot from the World Bank-directed Xiaolangdi project and have been active in adjusting their own regulations constantly. Chinese regulations, on paper, exceed international standard (World Commission on Dams, 2000: 108-110). Their implementation, however, is seriously lacking and plagued by corruption and related issues which caused major clashes between citizens and law enforcement units. In addition, China continues to build and plan large scale plants which will affect the life of ten thousands of people or even more. This situation is clearly unsustainable, resulting in a rating of -1.

The situation in Japan is very different. An extensive legal framework, combined with the fact that typically very few people are affected by hydropower development (due to the low population density in most hydropower deployment regions), as well as a good track record in cancelling projects that are opposed by the local population leads to a situation in which involuntary displacement is not an issue in Japan. Therefore, the situation is sustainable, resulting in a rating of +1.

5. Analysis

5.1 Comparison

Having analyzed each parameter for both the PR China and Japan, this chapter is comparing the assessment of the indicators for the two countries and is concluding in an overall evaluation of hydropower effectiveness in China and Japan.

The assessment of ***Generation Efficiency*** was unique among the examined indicators: it was based on five parameters (installed capital cost, capacity factor, economic life, operation and maintenance costs, cost of capital), but the very nature of LCOE as an indicator rendered a parameter based assessment redundant. Instead, the simple paradigm: The lower the LCOE, the more efficient the energy generation, was used as a benchmark. China has a hydropower LCOE ranging between 0.025 and 0.05 USD/kWh, which is at the very bottom of international price levels and indicates very sustainable generation efficiency. With a LCOE of 0.27 USD/kWh, Japan has one of the world's highest LCOE values, which indicates a highly unsustainable performance regarding this indicator.

China: +1 **Japan: -1**

The assessment of ***Inland Water Transport and Navigation*** was difficult due to the limited data availability. Fortunately, the general situation of the shipping sector in both China and Japan is clearly set out, allowing for a reliable evaluation even without specific parameters for hydropower development.

The PR China has a large Inland Water Transport sector which, inter alia, fulfils an important supply function for southern China. As a result, dams on the most important waterways – especially on the Yangtze River System – are without exception equipped with high capacity ship lift systems. In addition, the large scale of Chinese hydropower stations and their reservoirs creates a significant backwater effect. The analysis has shown that this backwater significantly reduces the risk of shipping by submerging shoals and opens up hundreds of kilometers of waterways for ships with higher tonnage. This also generates positive external effects by reducing the average cost for cargo transport by up to 37% and by decreasing CO_2

emissions. On the background of these benefits, it is apparent that hydropower has a highly positive impact on Chinese shipping navigation.

Japan, on the other hand, does not have a traditional IWT sector. Therefore, hydropower can neither negatively nor positively impact the current situation, resulting in a rating of 0.

China: +1 Japan: 0

The impact of hydropower plants on ***Irrigation*** was assessed according to one parameter: The amount of land irrigated exclusively through hydropower. China and Japan both exceed the Asian countries' average of 14.5%. According to the empiric data available for this paper's assessment, the value is significantly higher for Japan than for China, amounting to 26.2% and 17.6% respectively.

However, the analysis also discussed the issue of relying exclusively on these data, as they do not account for the major additions to the Chinese hydropower sector over the last decade. China continued its expansion not only in quality, with large scale projects like the Three Gorges Dam, but also in quantity: Since the year 2000, the Chinese total reservoir capacity grew by over 25%, which equals 100,000 billion m^3 (Food and Agricultural Organization of the United Nations, 2013b). In addition to that, the expected completion of the South to North Water Diversion in 2014 will further increase the amount of water available for irrigation by approximately 20%. Given that China and Japan both significantly exceed the average amount of land irrigated through hydropower development in Asia, the hydropower impact on water supply is clearly sustainable in both countries.

China: +1 Japan: +1

The indicator ***Greenhouse Gas Emissions*** did not only assess the traditional view of hydropower related GHG emissions, which are very low and mostly generated during the construction process, but also included state of the art findings about the GHG emissions of the dams' reservoirs. As the latter assessment is an extremely new approach, as well as technically and methodologically challenging, there is unfortunately no empirical data available yet. Discussion of recent research of this topic indicated, that GHG emissions in China are significantly higher on average than in Japan, both in absolute terms as well as per km³ of reservoir surface area. This assumption is supported by the fact that Chinese hydropower development over the past two decades has featured an average reservoir capacity that significantly exceeds prior values. For the 15 major hydropower plants built since 2000, the average reservoir capacity is 6.7 billion m³, which is ten times as much as the total Chinese average. In Japan, on the other hand, the 15 hydropower stations that have been built since 2000 have an average reservoir capacity of 0.078 billion m³ (Food and Agricultural Organization of the United Nations, 2013b). Considering the fact that Japanese hydropower plants tend to be built in mountainous areas with limited biomass reserves, as well as to be located further north than their average Chinese counterparts, it is apparent that the GHG emissions of Chinese reservoirs significantly exceed those in Japan.

Despite the strong tendencies indicating significant GHG emissions, there is currently not sufficient empirical data available to evaluate the influence of this indicator on the overall performance of hydropower. In the light of these findings however, it is also not justifiable to base an assessment on the “traditional”, construction based numbers for hydropower related GHG emissions. Therefore, this indicator will not be included in the final evaluation.

China: N/A **Japan: N/A**

In terms of ***Biodiversity***, this paper discussed the impact of hydropower during various stages of hydropower development and on various parts of the environment. It was concluded that it is neither feasible nor useful – due to the comparatively insignificant impact on these species – to include mammals or vegetable life in the analysis. Instead, the assessment focused on hydropower impact on endemic aquatic life. It was shown that hydropower stations affect these species far beyond the physical proximity of the plant and, therefore, the general amount of endemic fish species has to be considered. Japan’s endemic fish population consists of 56 endemic freshwater species, as well as 241 endemic marine species. China, on the other hand, has more than 440 fresh water species and 97 endemic marine species. Hence, the general impact of hydropower on endemic fish species is significantly higher in China compared to Japan, especially when considering the fact that among marine species, only a proportion (diadromous and anadromous species) are affected by hydropower. In addition, Chinese hydropower development has already led to the extinction of several endemic species, such as the Baiji dolphin. Given these circumstances, the biodiversity situation in

China is clearly unsustainable. While Japan performs better than China, its hydropower sector still exerts a negative impact on biodiversity.

China: -1 **Japan: -1**

The assessment of ***Sedimentation*** utilized one parameter: the amount of sedimentation that impacts hydropower plants (measured by the annual loss of reservoir capacity due to sedimentation).

While not included in the evaluation (see chapter 4.2.3), the sediment type was part of the analysis. China performs well in this regard: Given that the overwhelming majority of its hydropower infrastructure is located at the Yangtze and Huang He with their fine loess soil, the sediment structure is not damaging to dam machinery. Japan, on the other hand, has a high share of rock based sediment, as its hydropower stations are located closely to mountains, resulting in significantly increased wear and tear.

In terms of sedimentation rate, China features the world's second highest rate, with 2.9% reservoir capacity lost annually to sediment and is therefore confronted with a highly unsustainable situation. Japan, on the other hand, features a sustainable sedimentation rate of only 0.42%, almost one seventh of the Chinese one and far below the international average.

China: -1 **Japan: +1**

Safety was assessed based on three parameters: the regulatory framework, the exposure to (natural) earthquake risks and the respective dam performance, as well as the impact of reservoir induced seismicity. In terms of hydropower safety regulations, China and Japan both have sophisticated regulatory frameworks in place to ensure frequent inspections as well as to initiate necessary upgrades and repair processes in a timely manner. Given the high risk exposure of both countries, these measures are indeed necessary. China and Japan are both located in zones of very high seismic activity and frequently suffer from high magnitude earthquakes. Despite this, the safety performance of both countries' dams has been remarkable, even during two of the most devastating earthquakes in recent history (2008 and 2011).

The impact of Chinese and Japanese hydropower sectors on reservoir induced seismicity is the most significant difference in regards to safety. China experiences not only the most RIS related earthquakes worldwide, but also the ones with the highest average magnitude (see Annex 3). In Japan, RIS is a negligible issue: While there have been several reports, only a single case was of noteworthy intensity (magnitude of 4.1). Overall, both countries achieve a sustainable rating, although Japan performs better than China with three, compared to two, positive parameters respectively.

China: +1 **Japan: +1**

Community Engagement has been evaluated based on a single parameter: The degree to which affected communities can influence hydropower development in their area. Both countries have a history of weak civil movements during the 1970s and 80s of their modern history and in both cases the civil society has evolved and became more articulate and active in fighting for its interests. In Japan, this development took place within the legal and democratic-electoral framework: anti-dam movements fielded representatives for local and regional elections and campaigned extensively for their cause. After decades of fighting, they became proficient enough to put a halt to hydropower development in areas where the majority of the local population was opposing the projects, leading to a sustainable situation in 2013, in which the population’s rights and needs were included into decision making processes.

In China, on the other hand, the increasingly active anti-dam movements have been opposed by local authorities and ignored by the central government, leading to violent clashes, social unrest and a generally unsustainable situation. While there is a certain degree of grass-root democracy in the PR China in rural areas, this paper cannot assess the effectiveness of these processes. However, it has to be noted that, even during the past decade, anti-dam protests have ended in violent clashes with the authorities deploying massive numbers of law enforcement units. For these reasons, Japan performs clearly sustainable, while the situation in China is unsustainable.

China: -1 **Japan: +1**

The examination of ***Involuntary Displacement*** was based on three parameters: statistical data about the number of involuntarily displaced people, the legal framework for involuntary displacement and related issues (compensation, expropriation, etc.), as well as a case study based analysis to examine how the legal frameworks have been implemented.

The number of people displaced in China due to hydropower development is extremely high: According to current estimates, it amounts to more than 20 million. The reasons for this high number are twofold: Firstly, Chinese hydropower development is often based on very large scale plants that demand a large area to be cleared. Secondly, due to geography, the majority of Chinese hydropower stations are located in densely populated regions.

The situation in Japan is entirely different. Due to factors like the remote location of hydropower plants, the opportunity for affected citizens to stop hydropower development in their area, and the lesser scale of hydropower plants, there have been no major displacements over the last decade. While there are no numbers available for earlier times, the mentioned factors preexisted, which makes it reasonable to assume that the overall number of displaced people is lower than in China.

Regarding the legislative frameworks, it has been shown that Chinese legislation improved drastically over the past decades, especially with support from the World Bank. In particular, the 2006 revisions of the *Rules of Land Compensation and People Resettlement in Medium and Large Hydraulic and Hydroelectric Projects* emphasize a strong desire to support and protect people affected by *Involuntary Displacement*. However, the subsequent analysis of major *Involuntary Displacement* cases has also shown that there are severe issues regarding the implementation of said frameworks due to embezzlement and corruption.

The assessment of Japans legislative framework is not relevant, due to the fact that there is no issue of *Involuntary Displacement* present in the country. The assessment of *Involuntary Displacement* in the PR China has shown two negative and one positive parameter. In Japan, there is no record of noteworthy cases of *Involuntary Displacement*, indicating a sustainable situation.

China: -1 **Japan: +1**

Pillar	Indicator	China		Japan	
		Parameter	Rating	Parameter	Rating
Social	Community Engagement	No influence, opposed by local authorities (-)	-1	High influence, successful use of democratic/political structures (+)	+1
	Involuntary Displacement	High amount of ID cases (-) Resettler friendly legislation (+) Insufficient implementation (-)	-1	Very low amount of ID cases (+) Resettler friendly legislation (+) Sufficient implementation (+)	+1
	Safety	Legal framework (+) High RIS (-); Earthquake risk and dam performance (+)	+1	Legal Framework (+) Low RIS (+1); Earthquake risk and dam performance (+)	+1
	Average		**- 0,333**		**+1**
Economic	Generation Efficiency	Very low LCOE (+)	+1	Very high LCOE (-)	-1
	IWT and Navigation	Significant improvements in River Navigability (+)	+1	Not existent / No impact	0
	Irrigation	Above international average (+)	+1	Above international averages (+)	+1
	Average		**+1**		**0**
Environmental	GHG Emissions	High capacity Low reservoir age	N/A	Low biomass in reservoirs, Higher reservoir age	N/A
	Biodiversity	Large number of endemic freshwater fish species (-)	-1	Low number of endemic freshwater fish species (-)	-1
	Sedimentation	High sedimentation rate (-)	-1	Low sedimentation rate (+)	+1
	Average		**-1**		**0**
Overall Average			**-0,111**		**+0.333**

Table 5.1: Results Matrix

5.2 Conclusion

How effective is hydropower for the PR China and Japan in order to achieve their goals toward the development of their respective energy sectors?

To answer this research question, this paper utilized a sustainability assessment, examining social, economic and ecological indicators of hydropower with consideration of the distinct characteristics of each country.

As explained in chapter 3, the concept of Sustainable Development features a strict approach regarding the evaluation: sustainability of a research object can only be achieved, if all of its components are sustainable. As such, the concept of Sustainable Development is a binary one and per definition does not allow any gradation, i.e. something cannot be “somewhat” sustainable. As shown in table 5.1, the result of this paper’s sustainability assessment is that hydropower is neither in the PR China nor in Japan a sustainable way of generating energy. It has to be noted, that hydropower in China is unsustainable in two out of three sectors (social and ecological), while in Japan it is only in one sector (ecological).

However, “sustainable” and “unsustainable” give little evidence about the actual degree of effectiveness. In order to answer the research question and provide an accurate gradated evaluation of hydropower effectiveness, the assessment should be based on the average overall performance, instead of the concordant-pillar system.

Looking at the overall averages, China achieves a rating of -0.111, while Japan performs better with a rating of +0.333.

The fact that these results are relatively close is interesting, because the analysis has shown vastly different performances throughout all sectors. In the case of China, hydropower excels in the economic sector, featuring for instance the lowest LCOE of all major hydropower producing countries and extensive benefits to its IWT sector. This extraordinary economic performance is achieved through a strong emphasis on economies of scale in China, for which the Three Gorges Dam is the prime example. However, the same economies of scale are also responsible for “world-class” disadvantages in the ecological and social sectors, for instance the millions of involuntarily displaced people or the world’s second highest sedimentation rate.

The performance of hydropower in Japan is the antithesis of its Chinese counterpart. Japan excels in the social sector due to the lack of involuntary displacement and the influence exerted by affected communities on hydropower development, while it struggles to achieve a positive rating in the economic sector, featuring for instance the world's highest LCOE and, therefore, the most expensive hydropower generation.

To quantify this paper's result in more detail, it has to be kept in mind that the assessment ranged from -1 as the most negative outcome to +1 as the most positive outcome. Accordingly, hydropower in China operates at approximately 44.5% of maximum effectiveness, and while it offers major economic benefits, hydropower is not particularly effective when considering the complete set of advantages and disadvantages. Regarding improved social and ecological performance, hydropower is currently not able to fulfil China's self-proclaimed goals.

Japan, on the other hand, while receiving less economic benefits, has a far more balanced and overall better performing hydropower sector, operating at approximately 65% of maximum effectiveness.

This paper approached a relatively niche area of Sustainable Development theory and, as a result, has produced a large amount of new insights.

Unfortunately, this includes the "discovery" of a massive lack of essential information. Since Sustainability is an emerging and highly interdisciplinary academic field, gathering of suitable data sets is still mostly uncommon. Accordingly, the country-wide and sector specific sets of information necessary for this paper's analysis were not available for most indicators, requiring the author to gather and combine them from the individual academic fields of origin (e.g. geology, biology, etc.) or develop indirect ways to measure them.

This paper has been very frank in regard to any problems encountered, especially those related to data availability. Therefore, the display of just how much and what kind of data is missing for a transnational hydropower sustainability assessment is an important contribution to the field in order to improve future research work. This also applies to the lack of an applicable methodological approach, especially regarding indicators, which had to be developed and adjusted specifically for this paper's scale of analysis.

In addition to identifying existing gaps in the theoretical and empirical foundation, this paper also made a major contribution to the field of Sustainable Development theory by proving that country-level sustainability assessments vary according to the same kind of distinct social, economic and geographic characteristics that make single projects different from each other.

The analysis conducted in this paper was highly interdisciplinary, covering a multitude of different academic fields, such as geology, economy, social sciences, biology, engineering, and others. Moreover, an effort was made to value all aspects equally. As chapter 2 has shown, this is not particularly common, even among similar sustainability assessments.

Most importantly, this thesis generated a large amount of empirical results regarding hydropower performance in China and Japan. It has been proven that reservoir based hydropower in Japan provides more value compared to China. When combined with similar assessments of other energy types, these data could be used as guidance for policy makers, to choose which energy option would be the most suitable in their respective countries, according to the priorities of Sustainable Development.

Given that this paper approached a relatively new area of sustainability research, there is a wide variety of options for further research. First and foremost, the expansion of this paper: While the analysis covered nine important indicators from various academic fields, in a sector as intertwined and complex as hydropower, there are of course additional indicators that could be assessed to provide an even more precise and comprehensive result.

To expand the methodological foundation of this research, it would be especially important to develop more indicators for various approaches (e.g. specific industrial sectors, transnational comparison, etc.), as well as to develop more sophisticated and weighted scoring systems. This is particularly relevant in order to enable the comparison of different energy types, which would provide valuable information to improve development and deployment of future energy systems.

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7. Appendix

Appendix 1: Zusammenfassung

Die vorliegende Arbeit geht der Frage nach, wie effektiv Wasserkraft als Energiequelle ist um die Ziele der VR China und Japans hinsichtlich der Verbesserung ihrer Energieproduktion zu erreichen.

Aufgrund der Übereinstimmung dieser Ziele mit dem Konzept von Nachhaltiger Entwicklung, bildet eine Nachhaltigkeits-Analyse die Grundlage der methodologischen Herangehensweise dieser Arbeit. Diese orientiert sich konzeptionell an dem „klassischen" 3-Säulen Ansatz, wie er durch den Brundtland Report und auf dem Weltgipfel der Vereinten Nationen im Jahr 2005 entwicklelt wurde. Das Kernargument dieser Arbeit besteht darin, dass – ähnlich der Nachhaltigkeitsanalysen von geringerem Maßstab – die Nachhaltigkeit entsprechend geographischer, sozialer, etc. Vorausetzungen variiert. Die Analyse der Säulen basiert auf folgenden Indikatoren: die ökonomische Säule wird beurteilt anhand der Effizienz der Energieerzeugung, Auswirkungen auf die Binnenschifffahrt, und landwirtschaftlicher Bewässerung. Die ökologische Säule basiert auf den Treibhausgas Emissionen, Biodiversität, sowie Sedimentation. Die soziale Säule wird analysiert anhand von Sicherheit, Einbeziehung von betroffenden Bevölkerungsgruppen, sowie Zwangsumsiedlung.

Die Analyse hat ergeben, dass Wasserkraft in seiner derzeitigen Ausprägung in der VR China deutlich weniger nachhaltig ist als in Japan. Zwar profitiert China enorm von der außergewöhnlich guten Leistung im wirtschaftlichen Bereich, jedoch überwiegen die negativen Folgen in dem Bereichen Soziales und Umwelt deutlich. Japan hingegen hat ein ausgewogeneres Ergebnisprofil: Hervorragende Ergebnisse im sozialen Sektor, gepaart mit ausgeglichenen Ergebnissen bezüglich der ökologischen und ökonomischen Leistung.

Appendix 2: Abstract

This thesis aims to assess the effectiveness of reservoir based hydropower as an energy source for the PR China and Japan regarding the countries' self-proclaimed goals of improving social and environmental performance while also increasing the gross electricity production.

In accordance with these goals, a sustainability assessment builds the framework of the methodological approach of this paper. It is based on the "classical" three pillar model as developed by the Brundtland Report and the 2005 UN World Summit. The thesis argues that - similar to small scale sustainability assessments - the sustainability performance on a country scale will differ according to geographical, social, economic and other features of each country. The analysis of the three pillars is based on the following set of indicators: The economic pillar is assessed through generation efficiency, inland water transport and agricultural water supply; the ecological pillar through Greenhouse Gas emissions, biodiversity and sedimentation, while the social pillar is assessed by safety, community engagement and involuntary displacement.

The analysis shows that hydropower is significantly less effective in the PR China than it is in Japan. While offering excellent economic performance for China (achieving the best possible rating), it performs extremely negative in the social and ecological sector. Japan shows a more even performance of hydropower across the three pillars: It performs remarkably in the social sector and has a balanced performance regarding environmental and economic aspects.

Appendix 3: Proven Cases of Major RIS (Probe International, 2008: 2-3)

Name of Dam/ Reservoir	Location	Year	Magnitude of Earthquake
Marathon	Greece	1938	M = 5.7
Hoover	USA	1939	M = 5.0
Lake Crowley	USA	1941	M = 6.0
Kurobe	Japan	1961	M = 4.9
Xinfengjiang	China	1962	M = 6.1
Canelles	Spain	1962	M = 4.7
Kariba	Zambia	1963	M = 6.2
Monteynard	France	1963	M = 4.9
Grandval	France	1963	M = 4.7
Akosombo	Ghana	1964	M = 4.7
P. Colombia/Volta Grande	Spain	1964	M = 4.1
Kremasta	Greece	1966	M = 6.2
Benmore	N. Zealand	1966	M = 5.0
Piastra	Italy	1966	M = 4.4
Koyna	India	1967	M = 6.3
Banjina-Basta	Yugoslavia	1967	M = 4.5 - 5.0
Kastraki	Greece	1969	M = 4.6
Nanshui	China	1970	M = 2.3
Kerr	USA	1971	M = 4.9
Vouglans	France	1971	M = 4.4
Qianjin	China	1971	M = 3.0
Nurek	Tajikistan	1972	M = 4.6
Zhelin	China	1972	M = 3.2
Danjiangkou	China	1973	M = 4.7
Shenwo	China	1974	M = 4.8
Clark Hill	USA	1974	M = 4.3
Nanchong	China	1974	M = 2.8
Huangshi	China	1974	M = 2.8
Oroville	USA	1975	M = 5.7
Manicouagan	Canada	1975	M = 4.1
Lake Pukaki	N. Zealand	1978	M = 4.6
Monticello	S. Carolina	1978	M = 4.1
Hunanzhen	China	1979	M = 2.8
Aswan	Egypt	1981	M = 5.3
Srinakharin	Thailand	1983	M = 5.9
Bhatsa	India	1983	M = 4.9
Dengjiaqiao	China	1983	M = 2.2
Shengjiaxia	China	1984	M = 3.6
Khao Laem	Thailand	1985	M = 4.5
Wujiangdu	China	1985	M = 2.8
Lubuge	China	1988	M = 3.4
Dongjiang	China	1991	M = 3.2
Tongjiezi	China	1992	M = 2.9
Killari or ‘Latur’	SW India	1993	M = 6.1
Dahua	China	1993	M = 4.5
Geheyan	China	1993	M = 2.6
Yantan	China	1994	M = 3.5
Shuikou	China	1994	M = 3.2

Appendix 4: Curriculum Vitae for Oliver Neumann

PERSONAL DATA

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E-Mail	oliver.neumann.de@gmail.com
Date of birth	19/06/1986
Place of birth	Magdeburg, Germany
Nationality	German

WORK EXPERIENCE

01/2011 – 05/2011

Constituency Office of Undine Kurth, MdB (member of German parliament), *(Magdeburg, Germany)*

Intern

Responsibilities:

- Research, draft of briefing notes
- Representation of the Green Party in city council meetings on the matter of city PR and citizen communication
- Conduct of a public survey
- Data processing via WebCMS
- Organization of party meetings

09/2009 – 07/2010

Deutsche Post AG, Mail Delivery, *(Leipzig, Germany)*

Part-Time Employee

Responsibilities:

- Mail and parcel delivery

05/2007 – 09/2007

Weinor GmbH, Customer Support, *(Möckern, Germany)*

Full-Time Employee

Responsibilities:

- Customer service and operation of the respective EDP system
- Management of storehouse and customer service supplies

08/2006 – 04/2007

University Hospital Magdeburg, Center for Acute Dialysis, *(Magdeburg, Germany)*

Civil Servant (Zivildienst)

Responsibilities:

- Management of medical supplies
- Patient assistance
- Basic maintenance of medical machinery

EDUCATION

10/2011 – ongoing **Master of Arts in East Asian Economy and Society**
University of Vienna, Vienna, Austria
Department of East Asian Studies, Chair of East Asian Economy and Society

09/2010 – 12/2010 **Study abroad, Chinese Language Studies**
Renmin University of China, Beijing, People's Republic of China
Faculty of Languages (Scholarship from University of Leipzig)

02/2009 – 04/2009 **Study abroad, Chinese Language Studies**
Wenzao Ursuline College of Languages, Kaohsiung, Republic of China
Faculty of Languages

10/2007 – 09/2011 **Bachelor of Arts in Sinology (grade 1.9)**
University of Leipzig, Leipzig, Germany
Department of East Asian Studies, Chair of Sinology
Thesis Title: "Geo-Energy Politics of the PR China in Central Asia and Africa" (grade 1.0)

07/2006 **Abitur (A-levels)**
Otto-von-Guericke-Gymnasium, Magdeburg, Germany

LANGUAGES

Mother tongue German
Other languages English (Fluent - C2)
Chinese (Working knowledge - B2)
Japanese (Basic - A2)
Russian (Basic - A1)

COMPUTER SKILLS

- MS Office, SharePoint and equivalent open source software
- Internet research
- Web CMS, HTML, basic Java
- Image processing (Photoshop CS6, GIMP)
- Linux OS, Mac OS